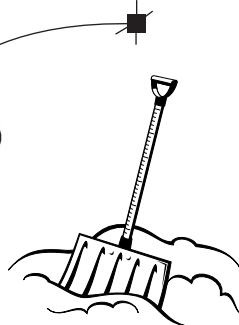


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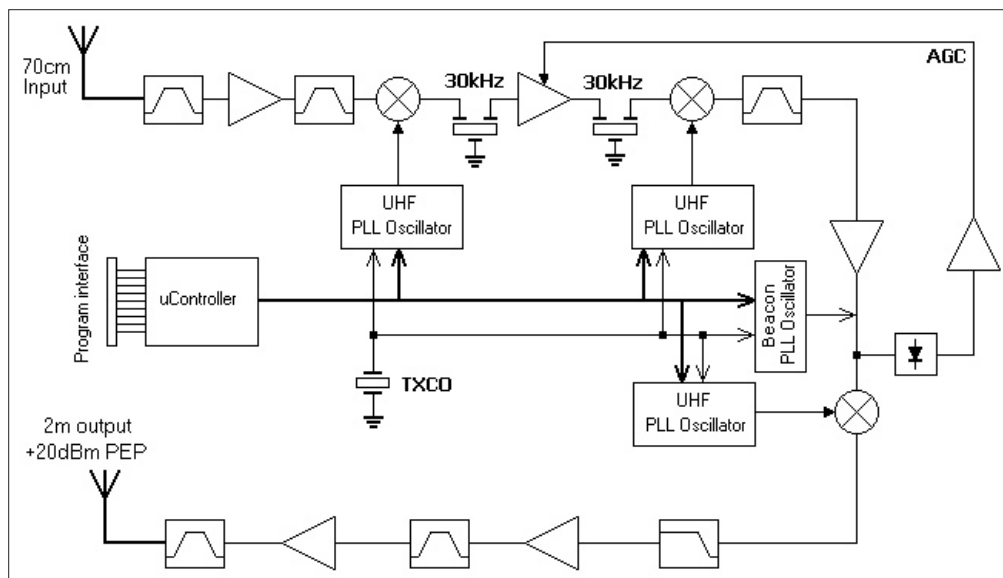


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JoAnne Maenpaa, K9JKM

Volume 31, Number 6

November/December 2008



Tiny Transponder!



Get out and work the satellites!

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How You Can Help Build New and Exciting Satellites

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Call the AMSAT-NA office at 301-589-6062 for questions on any or all of these ways you can help build new and exciting satellites.

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AMSAT Announcements

- If you participated in OSCAR SKN, please nominate someone you worked for Best Fist now, while you're thinking of it. Remember, your nominee need not have the best fist you heard, just the best of those you worked. Send your nomination to w2rs@amsat.org
- An upgrade to the RASCAL software to decode DO-64 telemetry is available at <http://www.delfic3.nl/rascal> - this page also includes the upgrading instructions if you are moving up from a previous version.

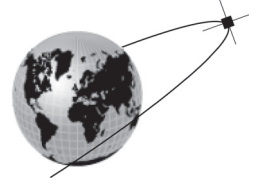
AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





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Happy New Year! I trust this holiday season has found each of our members in good health and good cheer. I realize that we are going through some difficult economic times, but I also know that there is much to be grateful for and that our members are making a difference in their communities and with AMSAT.

In December, AMSAT mailed to each of our members a fundraising letter centered on the President's Club. I hope you will consider donating to AMSAT and joining the President's Club to help make our common vision of 'wide area' and 'continuous coverage' a reality. AMSAT is dependent not only upon our talented volunteers to create the technology to be placed in orbit, but also the support of our membership to fund the work that we're doing to design, build, launch and operate the satellites as well. Each of us who want to see AMSAT succeed in space has an opportunity to help make our dream a reality by actively financially supporting AMSAT. Please help to make a difference.

This coming year (2009) is a significant milestone for AMSAT as we will be celebrating our 40th anniversary! In March 1969 AMSAT became a reality when the organization was incorporated in Washington, DC with Perry Klein (now W3PK) as founding President. Through the efforts of a dedicated group of volunteers, AMSAT has evolved into an organization recognized for demonstrating to the world that 'small satellites' have significant benefits as well as showing that it is possible to successfully develop (relatively) low cost satellites using off-the-shelf components. AMSAT has also inspired the creation of AMSAT organizations around the world, with each group focused on their nation's member's interest in putting Amateur Radio in space. We have been fortunate to cooperate on several projects with a number of these organizations (AMSAT-UK and AMSAT-DL in particular), which have resulted in the creation of several successful satellite projects, such as AO-10, AO-13, and AO-40.

During 2009 we will be taking time to celebrate our 40th anniversary through a variety of venues. The story of AMSAT will be told in the coming year in a series of articles to be published in *The AMSAT Journal*. The AMSAT booth at the Dayton Hamvention will incorporate a 40th anniversary theme

as well. We will also hold the 27th Space Symposium and AMSAT Annual Meeting in the Washington, DC area. Please mark your calendar for the weekend of October 9-11 (Columbus Day weekend) and join us at the BWI Sheraton Hotel to help us celebrate our 40th and lay the groundwork for the NEXT 40 years of AMSAT!

Let us also not overlook the fact that as I write this article, ARISS (Amateur Radio on the International Space Station) International is celebrating the silver anniversary of Amateur Radio in manned space. It was on December 8, 1983 that Owen Garriott, W5LFL, made the first two meter two-way communication with amateurs on the ground from the Space Shuttle Columbia on Mission STS-9. More recently, AMSAT has played an important role in manned space as part of ARISS International, chaired by AMSAT VP-Human Space Flight, Frank Bauer, KA3HDO. Our members are in the midst of building SuitSat-2 that we expect to be placed in orbit from the International Space Station sometime in 2009.

AMSAT Lab

In Spring 2008, construction of the AMSAT lab was completed in Pocomoke City, MD. Over the previous 18 months AMSAT relocated to the Hawk Institute for Space Sciences (HISS) the test equipment and clean room of our former P3-D Integration lab that was in storage in Florida. We paid for electrical and plumbing work related to fire suppression system needed to have the clean room meet the local fire code and built up the lab facility. AMSAT member Bob Davis, KF4KSS, was employed by HISS but also served in a critical volunteer position as the AMSAT lab Manager as well. A number of volunteers under Bob's leadership donated their time and 'sweat equity' to prepare the lab and to get all equipment up and running. Hundreds of man-hours were spent by Bob and the volunteers to prepare the lab for use by both HISS and AMSAT. Photos of the new lab were shown at the AMSAT Forum during the 2008 Dayton Hamvention. An article on the new lab was published in *The AMSAT Journal* as well (KF4KSS

continued on page 27 ...



Linear Transponder for CubeSat and Balloon Missions

by William Leijenaar, PE1RAH, pe1rah@yahoo.com

It has been some time since my transponder design was launched into space on board the Indian HAMSAT satellite. That was in 2005, but in the meantime I haven't stopped my activities on new transponder projects.

After my experience with the Indian HAMSAT, which was relatively small in size, I designed the P3E Mode-UV transponder, which was quite big. After finishing this project I wanted to focus on very small transponders for use in CubeSat and balloon projects. The CubeSats are very popular these days and it would be perfect to have a transponder design that fits in such a small CubeSat box. For me it was more a technical challenge to design a smaller and more lightweight transponder without sacrificing technical performance.

We already have seen a linear transponder on the Delfi-C3 satellite. My goal was to make a transponder that fits in a single CubeSat structure. Such a small transponder would also be very interesting for balloon missions or it can be used as the basis for a terrestrial transponder on top of a high mountain.

The small sized mode-UV linear transponder

- The transponder has been made completely with surface mount parts. Most are of 0402 size. (Approximately .040"W x .020"L x .024"H – tiny indeed – Ed.) To save weight and space the input and output connectors are SMD coaxial types. The power supply has been made with direct solder contacts due to the high currents where it is better to have a permanent solder contact.

The block diagram of the transponder can be seen in Figure 1.

The input signal in the 70cm amateur band is first filtered by a SAW filter and then amplified by a low noise amplifier. Next it is mixed down to the first IF, which sets the transponder bandwidth of 30 kHz.

The transponder makes use of two IF frequencies. The first one determines the bandwidth of the transponder with two flat and sharp edge crystal filters. The second IF frequency is in the UHF range and that makes filtering easier at the 2m output side. At the second IF the power level is monitored and used for the AGC feedback, which is regulated by the first IF amplifier.

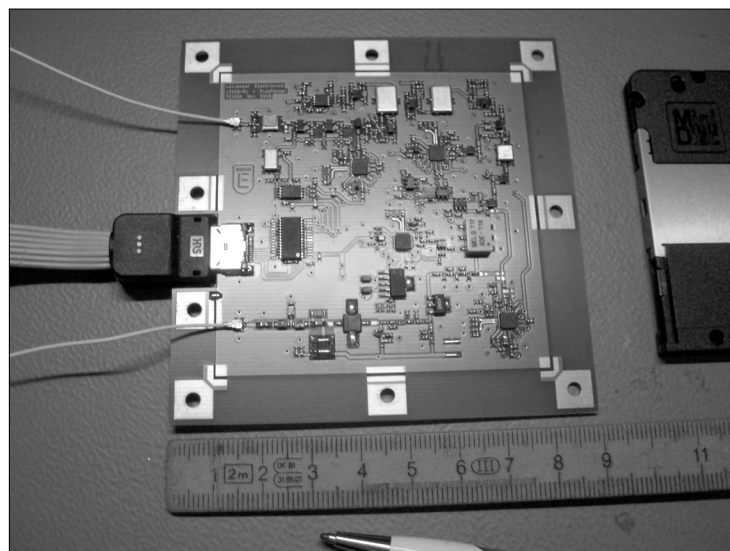


Photo 1: Photograph of the transponder.

with CW beacon includes:

- The total board is only 9cm x 9cm x 5mm, including the 1 cm mounting strip around the actual transponder circuit. The board runs on a single power supply that can be between 3.0 and 4.0 VDC. The transponder output on 2m is 200mW PEP, with a 3.7VDC power supply.

freely to the needed frequency. This makes the design useable not only for space applications but also for terrestrial missions, or as an IF to higher frequencies. The programming of the PLL's is done by the onboard microcontroller of the MSP430 family and has an ISP port to the outer world. The onboard beacon PLL can be switched on/off by the microcontroller and can generate a pre-programmed CW message.

At the second IF the CW beacon is injected and both the passband and CW beacons are then down-converted to the 2m VHF range. A sharp low pass filter then makes sure that no unwanted images, spurious and or oscillator signals will enter the final power amplifier.

All four oscillators on the board are PLL types that can be programmed

The development of the transponder took more than two years because many problems occurred. The major two problems were the bandpass filter circuit and the low voltage 2m power amplifier.

For the bandpass filter I have ordered many kinds of filters, and tested all kinds of circuits. It took me more than three months to get it as perfect as I wanted and the result is a flat bandpass curve that is stable with regard to temperature and doesn't need tuning. See Photo 2.

The low voltage 2m power amplifier was one of my major concerns as unsatisfactory results would make the whole project unfeasible. Power amplifiers on 2m are already difficult to find in modern components as the UHF and SHF frequencies are more popular. Also to get a VHF amplifier to work on a single 3 VDC supply is even more difficult to achieve. These days there are several low voltage power amplifiers available for the 800 MHz to 1.8 GHz band. This means they are normally used for this region and have their application circuits in this range. The problem is that most of the transistors are internally matched and can not be used for other frequencies. When the transistors are not internally tuned they can be used on lower frequencies. It should be noted that these transistors often are potentially unstable in the lower frequency regions and proper circuit design is needed to make the device stable under all conditions.

Shown in Photo 3 is one of my first trials with a 2m power amplifier at a 3.7 VDC supply. This 2m power amplifier provides 2W output power with a gain of approximately 9 dB.

The amplifier used in my transponder uses a similar device and circuit. The maximum power of the device is about 2W, but this is far in the compression region. This is the reason for the relative low gain of 9 dB. In the transponder I use the transistor in a lower power range of approximately 200 mW where the linearity is much better and the gain is in the order of 13 dB.

The entire project was completed in the late night hours after my daily work as an RF development engineer at NXP Semiconductors. The assembly of the board was done by hand, which takes a lot of time to do. To give you an idea of the magnitude of assembly required, the board has a total

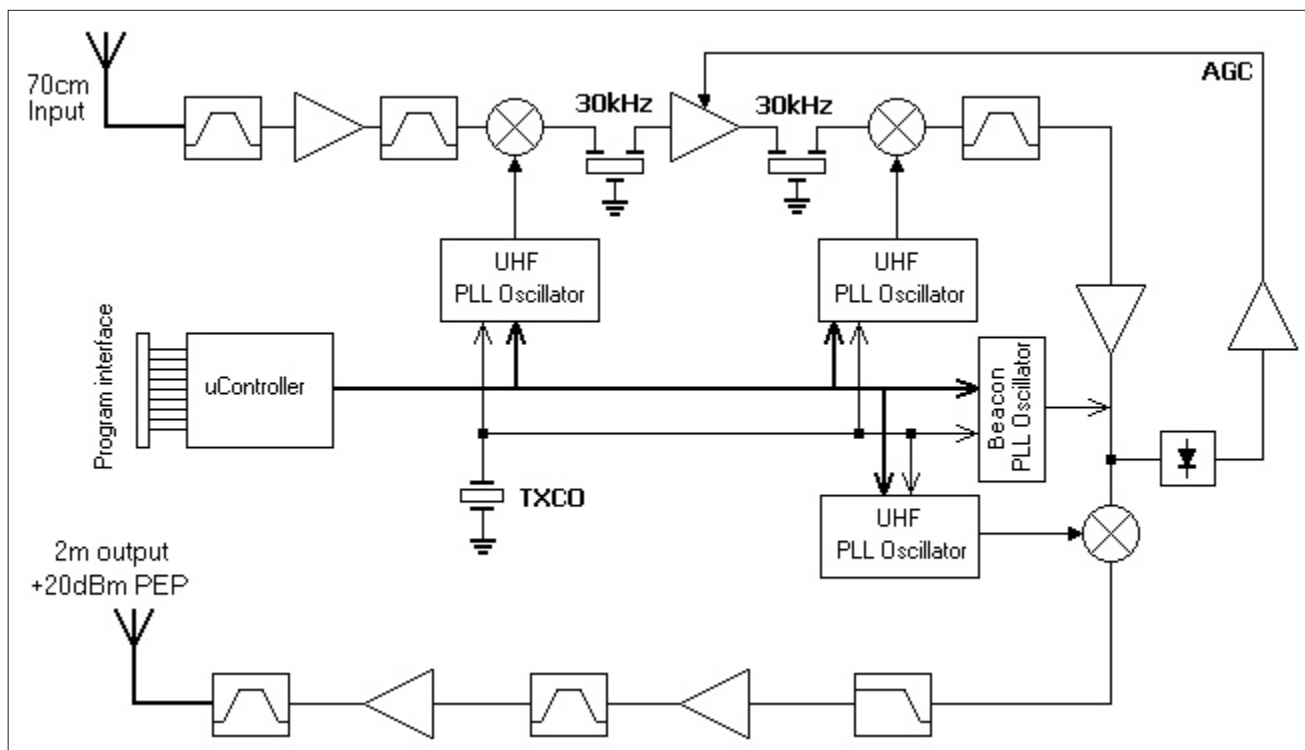


Figure 1: The transponder block diagram.

of 310 components of which most have more than two pins to solder.

I will make some more boards available for groups that are interested in this transponder to use it in their project for a nominal cost. I will try to get some linear transponders available for amateur projects and events. The cost will help me to get some of my money back that I have spent in those two years on developing this very small transponder. ☺

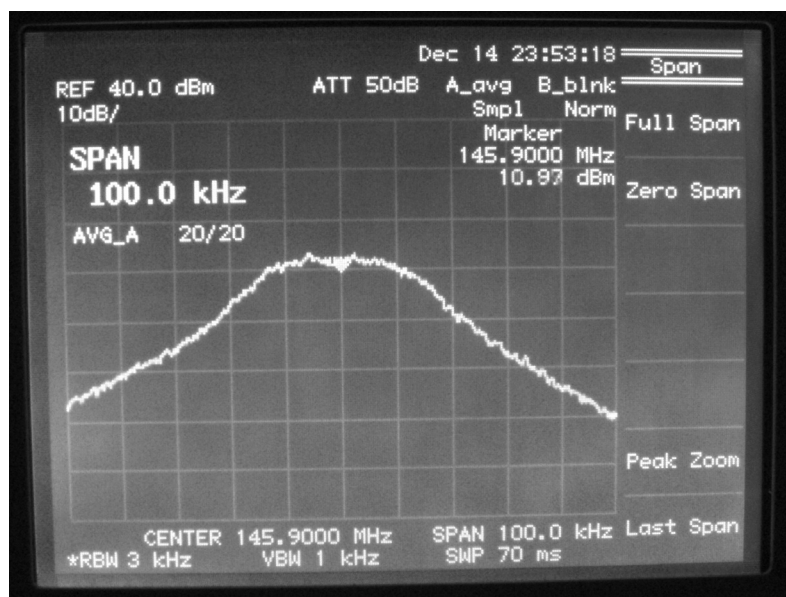


Photo 2: Spectrum analysis of the transponder bandpass.

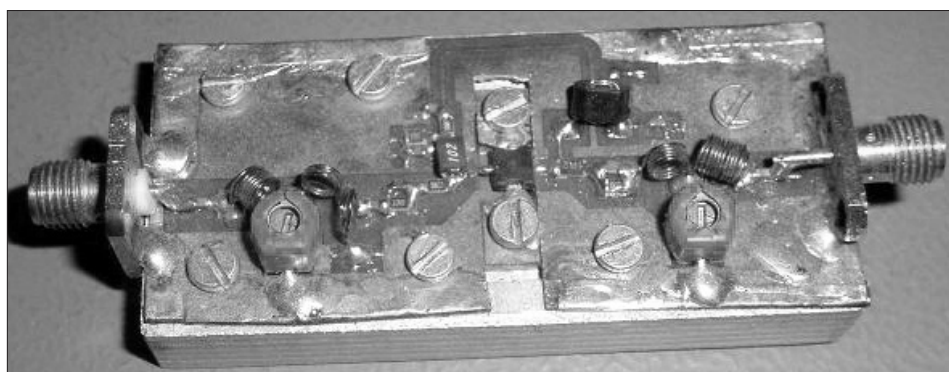


Photo 3: The 2m power amplifier.

Handheld FM Satellite Stations – Meeting FCC Part 97.1 with a Superb Tool for Recruiting New Operators

by Timothy J. Lilley, N3TL, n3tl@amsat.org

Abstract

Several times a day, American Amateur Radio operators are using low-cost handheld stations to demonstrate the entirety of FCC Part 97.1, which defines the fundamental purpose of the Amateur Radio service. These handheld stations are superb tools for use in recruiting new licensed amateurs – especially

Xbox 360 game console and a handful of games to play on it.

The process of preparing for and effectively participating in a pass of any Mode-J satellite calls for HHS operators to develop and use skills that specifically address the fundamental purpose and basis for the U.S.

LEO-satellite pass, portions of Central and South America (and even western Europe for amateurs in the northeastern U.S. and eastern Canada) will reward and strongly reinforce the investments of time and money necessary to earn an amateur license and get on the air.

The Handheld Satellite Station (HHS)

I define a handheld satellite station (HHS) as a single dual-band handheld radio capable of at least semi-duplex operation and a single handheld antenna. The radio and antenna must accommodate narrow-band FM transmission on the 2m frequencies noted in the table above and reception of narrow-band FM on the 70 cm frequencies noted in that table.

As I write this, Alinco, Icom, Kenwood and Yaesu all have handheld radios in their current lines that offer at least semi-duplex, crossband operation, which permits Mode-J satellite contacts. The only currently available handheld radio I have used is a Yaesu VX-7R, which is the example featured in this paper. It is not intended as a recommendation of Yaesu or the VX-7R over any other currently available handheld. It simply is the current-model radio I own. Since becoming active on the Mode-J FM satellites, I have purchased a used Icom W32A handheld, a discontinued model that offers full-duplex crossband operation. I believe it is important

Satellite	Dimensions	Weight	Apogee	Perigee	Uplink	Downlink	Launched
AO-27	15cm Cube	11.80 Kg	800 Km	789 Km	145.850 MHz	436.795 MHz	26 Sept., 1993
AO-51	24cm Cube	11.14 Kg	818 Km	696 Km	*145.920 MHz	*435.300 MHz	28 June, 2004
SO-50	35cm Cube	10.00 Kg	713 Km	603 Km	**145.850 MHz	436.795 MHz	20 Dec., 2002

* Alternate frequency pair of 145.880 MHz up and 435.150 MHz down sometimes operational.

** CTCSS tone of 67.0 Hz required at transmit.

Sources: www.amsat.org, www.spacequest.com and "Getting Started with Amateur Satellites," by G. Gould Smith, WA4SXM.

young people – and, as such, should be at the forefront of efforts to promote Amateur Radio to the public.

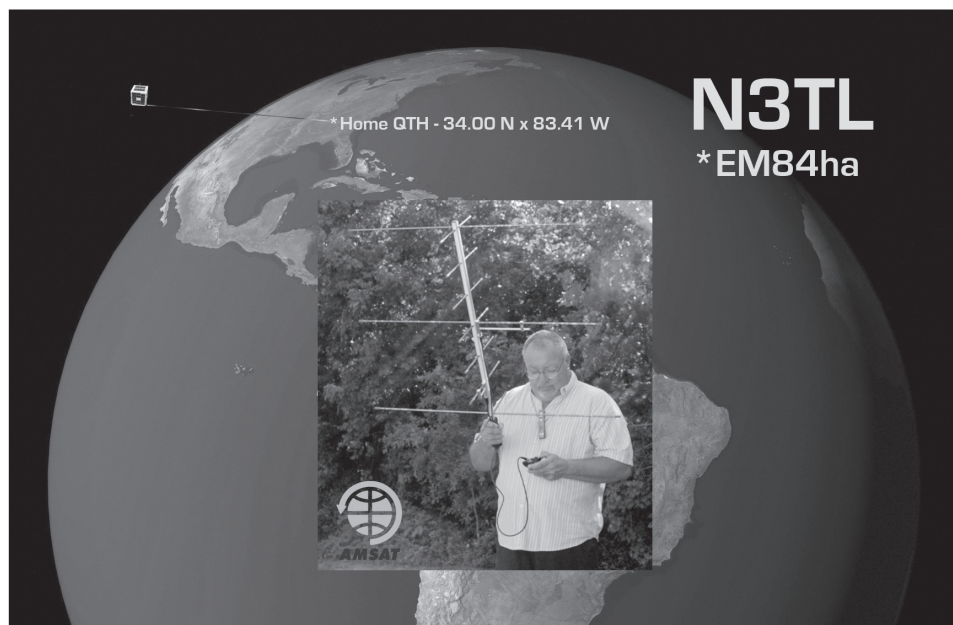
Introduction

There currently are two Amateur Radio satellites in Low Earth Orbit (LEO) equipped to permit crossband operation using narrow band FM. Working these satellites with a handheld satellite station (HHS) provides many benefits to an amateur operator, and all of them are enhanced by the fun and excitement of making contacts in orbit! No licensed amateur should trivialize the remarkable feat that dozens of hams achieve on every pass – they make contact with fellow hams by transmitting VHF, narrow-band FM signals several hundred km above Earth to a tiny LEO satellite. Each of these satellites – AO-51 and SO-50 – serves as a crossband repeater, capturing those 2M VHF signals and retransmitting them in the 70 cm UHF band using very low power. This VHF-up/UHF-down crossband operation is designated Mode J.

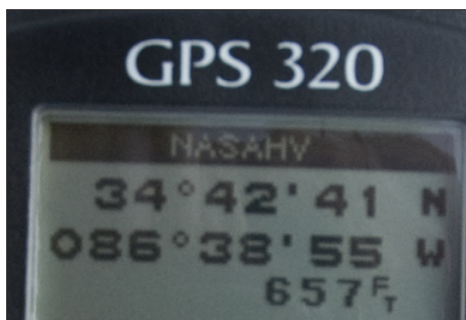
The relatively low cost of building a consistently effective HHS is just as remarkable and significant as the achievement of making contacts in orbit. Notwithstanding the many opportunities to experiment with simple homebrew antennas for HHS operation, a newly licensed amateur who might not feel ready to experiment with antenna design and construction can pick up everything necessary to get an effective HHS on the air for *less* than the cost of an

Amateur Radio service, as outlined in FCC Part 97.1. In the process, they are further refining the talents and skills necessary to provide the most effective communications possible in emergency and other public-service situations.

For these reasons, I believe that handheld satellite stations can and should be key components of efforts to recruit new amateur operators, young and old. The excitement of making contacts in orbit cannot be overstated. Successful HHS contacts with operators across North America and, depending upon location and the footprint of a given



The QSL for N3TL satellite contacts includes a photo of my first HHS.



Use a GPS reading to determine your Maidenhead grid square.

to note that, while full duplex is not essential to effective HHS satellite operation, it is recommended because full duplex reduces multiple/simultaneous transmissions (i.e., operators can avoid “stepping on each other” when trying to make contacts) and a blank downlink. I hope the major manufacturers will consider adding full-duplex-capable models to their current and future lines of VHF/UHF dual-band handheld radios.

Arguably the most popular commercially available antenna for HHS satellite contacts is the Arrow 10 WBP, a dual-band Yagi with a 10-watt-maximum duplexer that features three elements for 2m and seven elements for 70 cm. With elements made from aluminum arrow shafts (thus, the brand name!) and a two-part boom, the Arrow can be assembled and disassembled in a couple of minutes. I used an Arrow dual band Yagi while completing the research for this article. Since then, I learned about another option – the Elk Antennas 2M/440L5 dual-band log periodic antenna. The Elk is now my primary HHS antenna for several reasons. Most importantly, it has proven consistently more effective for me on the receive side. Its design eliminates the need for a duplexer, and the Elk is rated to handle much more power than the Arrow with its duplexer. In researching the Elk, I discovered a thread on the AMSAT bulletin board (AMSAT-BB) in which it was reported that the Elk does not provide acceptable performance (i.e., the ability for an operator to hear the downlink while transmitting) in full-duplex operation. That has not been true for me and I have recorded audio to prove it. The Elk also retails for roughly \$50 less than the Arrow. Anyone new to working AO-51 and/or SO-50 with a handheld station will find the performance of either the Arrow or the Elk to be more than adequate. From here, I believe that side-by-side comparison will favor the Elk more often than not. All of this being said, there are times and situations when the Arrow or the Elk might

not be preferred for HHS use. In those cases, there are smaller, more convenient options. The Pryme AL800 is a telescoping whip antenna that I have used as part of my HHS for a series of contacts through SO-50 and AO-51. The MFJ 1715 and 1717 are “duck” antennas that also provide useful service as HHS antennas. I learned of the AL800 and the MFJ ducks from AMSAT member Allen F. Mattis, N5AFV. He has an extensive report on his use of the AL800 on his Web site, www.qsl.net/n5afv/. I also now own and use as my preferred whip antenna, a Diamond SRH-789. It performs at least as well as the others, and it also performs well as a receive antenna on the shortwave broadcast bands, which my VX-7R includes. Performance loss when using a whip instead of the Arrow, Elk, or a similar, homebrew design occurs most notably on the receive side, based on my experiences with these various antennas. As a licensed amateur, my interest in experimentation and homebrew projects has focused primarily on antennas – especially those that permit consistent operation in portable/emergency situations. When it comes to HHS antennas, operators have a wealth of information and designs available from the Internet. Typing the phrase “Homebrew LEO Satellite Antenna” into a Google search window produced more than 2,000 listings! Here are a couple of links to get you started:

<http://www.qsl.net/vk3jed/2m70cmant1.html>

<http://www.wa5vjb.com/references/Cheap%20Antennas-LEOs.pdf>

It is imperative that *every* amateur satellite station include the most sensitive receiving system an operator can assemble. Amateurs who are new to the satellites must account for the very-low-power signals they are trying to capture from LEO. I like to use SO-50 as my example because it transmits a quarter-watt into a quarter-wave (i.e., 0 gain) antenna mounted on one of its corners. I have worked many passes when stations that are loud, clear and strong into the satellite obviously are not receiving nearly as effectively as they are transmitting. The antennas mentioned in

this paper will provide HHS operators with the ability to effectively receive satellite signals. However, that should not keep any amateur from doing everything possible to optimize reception.

Antenna polarization also will affect reception, and it can (and usually does) change during the course of one satellite pass. The HHS antennas featured in this paper are linear-polarized. The Arrow dual-bander provides a 3-element 2M Yagi and a 7-element 70 cm Yagi mounted at a 90-degree angle to each other on one boom. The Elk provides 10 elements oriented in the same plane. The SRH-789, AL800 and MFJ duck antennas are verticals. HHS operators will discover quickly that even small changes in these antennas’ orientation can make big improvements in reception quality. Anyone interested in learning more about polarization should check out this Web site:



Compass, GPS and HHS - everything any operator needs to make HHS satellite contacts anywhere.

http://www.analyzemath.com/antenna_tutorials/antenna_polarization.html

There have been passes when I have rotated the Arrow antenna through a 90-degree arc to maintain optimum signal quality from AOS to LOS. Making slight adjustments in antenna orientation quickly and easily (i.e., with a slight twist of the wrist) can make the difference in completing a contact. The Elk has not suffered signal loss from polarization change nearly as much as the Arrow, which is another reason I prefer it. However, there are occasions when changing its polarization is not only necessary, but effective.





N5AFV with his 9,000+ contact HHS. Photo courtesy N5AFV.

Earlier, I stated that it was possible to “pick up everything necessary to get an effective HHS on the air for less than the cost of an Xbox 360 game console and a handful of games to play on it.” That statement is based on using one of two radios – an Icom IC-T7H or a Yaesu FT-60R – with a Pryme AL800 whip antenna. I have seen these radios advertised on the Web for \$175 and \$185, respectively. I bought my AL800 whip for \$34.95. That’s roughly \$210 and \$220, plus tax, for either of these radios and the AL800 antenna. As this paper is being written, the lowest advertised retail price I could find for the xBox 360 game console was \$199.99.

Handheld Satellite Stations and FCC Part 97

FCC Part 97.3-(4) defines the amateur service as – “A radio communication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.”

FCC Part 97.3-(3) defines the amateur-satellite service as – “A radiocommunications service using stations on Earth satellites for the same purpose as those of the amateur service.”

Before defining what the amateur service and its subset, the amateur-satellite service, are, FCC Part 97.1 presents the five principles the U.S. Federal Communications Commission has adopted as the elements of the fundamental purpose of the amateur radio services in America. As noted in this paper’s Introduction, I believe that licensed operators using handheld stations for satellite contacts on AO-51 and SO-50 are

specifically addressing each of those principles every time they activate their stations.

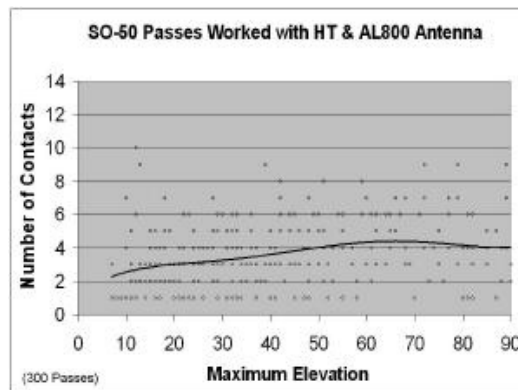
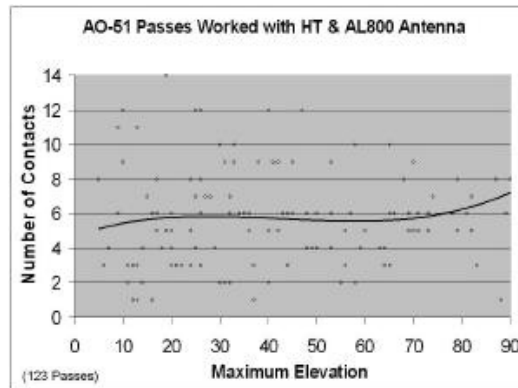
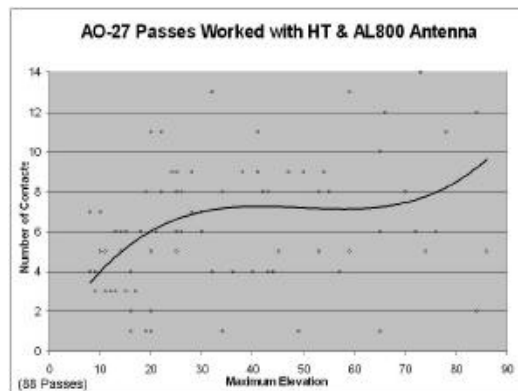
Principle: FCC Part 97.1(a) – “Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.”

HHS Application:

Throughout the 1980s and early 1990s, I served as a member of the Amateur Communications Team that worked with the Johnson County (Kansas) Emergency Operations Department. Serving both as a certified storm spotter in the field, and also as a net control operator, I had an opportunity to learn about and apply the skills necessary for effective, timely communication in an emergency situation. In the field and from the net control chair in the county’s Emergency Operations Center, I learned quickly that amateurs who choose to get involved in emergency communications must be able to transmit pertinent information quickly and clearly. Those in the field also must be able to receive information from net control accurately – preferably without the need for repetition.

I dare say that few non-emergency Amateur Radio situations help operators hone the skills described above like HHS operation. Even though the LEO provides a relatively small geographic “footprint” during a given satellite pass, that footprint still opens communications to a large part of North America. Southern portions of passes also put HHS operators within range of stations in Central and South America. As a result, there are many operators using stations of all kinds trying to access the same satellite for contacts, some even DX. That fact creates opportunities for skills improvement on every pass.

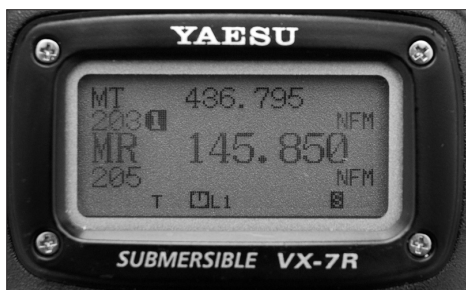
Operators often must deal with conditions that sound as chaotic as any HF DX pileup I have ever heard or tried to work. Successful contacts happen when HHS operators are able to communicate clearly and quickly; not only because they are among many other stations competing for contacts, but



Tables courtesy of N5AFV.

also because the operating window for a given pass rarely exceeds 10-12 minutes for the HHS. My experiences suggest that, even in the best of cases, HHS operators will generally acquire the satellite at around 3-4 degrees elevation, and lose the satellite at about the same elevation on the other side of the pass. There are always exceptions, of course, but day-to-day HHS operation rarely will prove effective at satellite elevations lower than 3-4 degrees. From my home QTH, I have logged and recorded (via digital recorder) a contact with Clint Bradford, K6LCS, when AO-51 was at 4.1 degrees to my west/northwest. This is a tribute to the effectiveness of the HHS because Clint was in a Tarzana, California, parking lot doing a demo using his HHS. That two-way HHS contact is a great illustration of the potential for HHS operation.





Note L1 at the bottom of the display. It represents a power level of 50 mW out on the Yaesu VX-7R.

In addition, all operators who attempt satellite contacts must learn about and account for the Doppler effect in real time. Because of Doppler, the received frequency is higher than the transmitted frequency when a receiver and transmitter are approaching each other. When they are departing from each other, the received frequency is lower. At some point during each satellite pass, the receiver and transmitter are neither moving toward nor away from each other, so there is no Doppler shift. At the uplink frequencies on 2 meters, the Doppler range is lower than the 5kHz bandpass, so HHS operators do not have to adjust their transmit frequency. They do, however, have to retune their receivers during every pass to account for Doppler. Operators who are new to working AO-51 and SO-50 should start listening for each satellite at 10 kHz above its listed receive frequency. As a pass unfolds, they should expect to tune down in 5 kHz increments when signal quality begins to deteriorate. By LOS, they will be listening 10 kHz below the satellite's listed receive frequency.

Richard Hackney, N1ASA (SK), wrote a clear and concise explanation of the Doppler effect, including examples of how Doppler affects the receive frequencies of AO-51 and SO-50, in "'Down-to-Earth' Satellite Communications," which is available online here:

<http://www.wku.edu/ksgc/sats.pdf>

Patrick Stoddard, WD9EWK, has written a great tutorial that's available on the AMSAT Web site:

www.AMSAT.org

Clint, K6LCS, also has a great HHS tutorial online at:

<http://www.clintbradford.com>

Amateurs who choose the HHS for their satellite work inevitably will become better operators, and their improved skills will pay big dividends in any public service/emergency situation.

Principle: FCC Part 97.1 (b) – *"Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art."*

HHS Application: This is the critical principle as it relates to using a HHS to introduce Amateur Radio to the public and newcomers, and to recruiting new licensed operators of any age. For the purposes of this discussion, I will expand the concept of "contributions to advancement" beyond just the "radio art" specified by the FCC.

My decision to begin working the FM LEO satellites with a HHS required more than just finding the frequencies I needed for crossband operation and assembling my Arrow handheld Yagi. I had to learn how to find and track the satellites as they moved across the sky, and I had to learn the information necessary to provide my location during contacts. In preparing for my first few HHS satellite passes, I discovered a number of exercises that will expose newcomers to more than just Amateur Radio. These exercises will definitely help anyone contribute to advancement of more than just radio art because they will expose newcomers to concepts and activities that will expand their knowledge.

I learned quickly that I needed to know my precise location so I could accurately provide it as a Maidenhead grid square. I used my handheld GPS unit to find the coordinates of my home QTH and then used grid square calculators on the American Radio Relay League (ARRL) and AMSAT-NA Web sites to confirm my grid square. That proved important because online "lookup" sites, including QRZ and Hamcall, listed me in a different grid square based on my zip code. It turns out that I operate my HHS from just slightly north of the EM83/EM84 boundary, in EM84. I updated my listings at QRZ and Hamcall to reflect this.

I also used my coordinates to generate schedules of the FM LEO satellites on the AMSAT Web site. Later, I added tracking software to the home computer for this purpose, but that step is not necessary for HHS operators who are just starting out. They can get the information they need online from AMSAT, as I did. Those schedules provide the overall duration of a pass, Acquisition-of-Signal (AOS) time and azimuth position, maximum elevation and azimuth position, and Loss-of-Signal (LOS) time and azimuth position.

When I generated my first schedule for AO-51, something clicked. I realized immediately that any new HHS operator had a way to practice and refine the ability to follow the tiny FM LEO satellites as they track across the sky several hundred kilometers overhead. The schedule I printed looked very similar to the one I had been printing for years from the Heavens Above Web site for visible passes of the International Space Station (ISS). Having marveled literally hundreds of times at the silver-white dot racing silently across the night sky above me, I realized that all of those ISS passes were practice for tracking AO-27, AO-51 and SO-50.

I quickly located the orienteering compass that I've had for more than 30 years. In the days before GPS, a compass like this one and a map helped everyone who spent time outdoors navigate in the wilderness and keep track of their positions. I use it now to get my bearings for and visualize every satellite pass I work with my HHS. I note landmarks that coincide with the azimuths for AOS, maximum elevation and LOS. I then use the markings on the compass to get an eyeball reference on maximum elevation. Having these reference points makes it quick and easy to visualize how the satellite will track as the pass unfolds. This approach has proven itself time and time again as a great way to pick up the satellite quickly and stay on it from AOS to LOS.

Many amateurs around the world are using home stations with wonderfully complex and effective antenna systems that feature azimuth and elevation rotator systems connected to a computer in the shack. They use software like SatPC to not only control the rotators and track the satellites, but also to automatically and accurately tune their radios to account for the Doppler Shift during a pass. I will suggest here that HHS operators develop a better understanding of the tracking principles involved, one that will serve them well in an emergency situation. Finding and reporting their precise location becomes second nature. Finding the bearings they need to point a directional antenna toward net control also becomes second nature.

The very fundamentals of HHS operation require amateurs to not only contribute to the advancement of the radio art, but also to contribute to the art of quickly and accurately finding and reporting their locations, and to using the skills necessary to generate the most effective signals possible.

Principle: FCC Part 97.1 (c) – “Encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art.”

HHS Application: Much of what appears in the previous section arguably could be included here. Instead, I choose to focus in this section on two concepts that speak directly to advancing communication and technical skills. The first is HHS operation with very compact antennas. The second is HHS operation using very low power.

Telescoping-Whip-Antennas for HHS Operation

Allen F. Mattis, N5AFV, has made more than 9,000 HHS contacts on the LEO FM satellites using a handheld transceiver with a Pryme AL800 telescoping whip antenna. Allen has generated significant data on whip-antenna performance in his HHS operation, and it is available on his Web site – www.qsl.net/n5afv/.

Allen’s ongoing research and HHS operation using only a whip antenna is a great example of the ways HHS operators are improving their abilities to prepare for emergency communications by learning the most effective ways to use a whip antenna in HHS satellite operation. I encourage everyone to visit Allen’s Web site to learn just how consistently effective HHS satellite work can be with nothing more than a telescoping whip. Such operation undoubtedly will help prepare any amateur to quickly establish effective communication in an emergency situation. Allen’s contact summaries, by satellite are shown on page 8.

Very Low Power for HHS Operation

Imagine the worst. Without warning, you find yourself in an emergency situation that demands communication – and all you have for power are alkaline batteries for your HT. Would you be surprised to learn that as few as two AA batteries could enable you to cover hundreds of kilometers with a VHF signal? They can, and they have for the N3TL handheld station. When I began HHS operation on the LEO FM satellites, I began wondering how low I could go – not in elevation to hear and work a satellite, but rather in output power to reach orbit with an effective signal. That curiosity spawned the “Duracell Experiment.” Included as Appendix A is a report of the 51 satellite contacts I made using one set of two AA Duracell batteries, with the RF output on

my Yaesu VX-7R set to 50 mW.

Even with the gain provided by the handheld Yagi, my RF output was lower than SO-50’s quarter-watt RF out. I earned AMSAT Satellite Communications Achievement Award number 473 using only confirmed contacts on 50 mW RF out, having worked 20 states, Ontario, Mexico and Venezuela. Here is a summary of contacts during the “Duracell Experiment,” by satellite:

SAT	CONTACTS	AVG ELEV	AVG RANGE
AO-51	32	37.878 DEG	1274.468 KM
AO-27	13	34.269 DEG	1452.774 KM
SO-50	6	30.850 DEG	1386.619 KM

FCC Part 97.1 (c) pertains to rules which provide for advancing communications and technical skills. I submit that current rules permitting newly licensed amateurs with a Technician class license to begin HHS satellite operation are precisely intended to permit the kind of research Allen, N5AFV, and I have undertaken with antennas and very low power, respectively. In the process, any amateur who tries HHS operation with either or both will also improve his or her operating skills.

Principle: FCC Part 97.1 (d) – “Expansion of the existing reservoir within the Amateur Radio service of trained operators, technicians and electronics experts.”

HHS Application: HHS operation is a wonderful tool to recruit new Amateur Radio operators and, as a result, specifically address Part 97.1 (d). Consider:

- HHS demonstrations take very little time because of the nature of satellite passes.
- The “band **will** be open,” permitting contacts with stations within the footprint of a given pass.
- Those who are unfamiliar with Amateur Radio will be exposed to the ability to make contacts with stations hundreds, even thousands, of kilometers away using equipment they can hold in their hands.

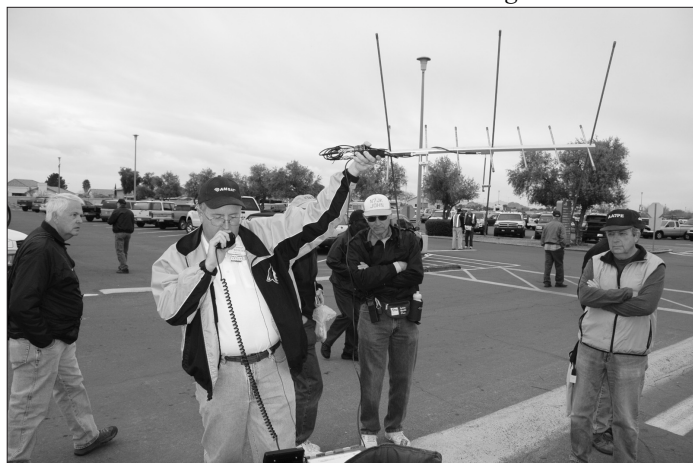


Clint, K6LCS, does a satellite demo using his HHS. Photo courtesy K6LCS.

- The most basic of Amateur Radio licenses is all it takes to get on the air and into orbit.
- The cost of a very effective handheld satellite station is relatively low – less than the cost of an xBox game system and a few games, as noted earlier.

I believe that any licensed operator who is interested in the growth and future of Amateur Radio should assemble and begin using a handheld satellite station for contacts on the FM LEO satellites. After only a few passes, any operator will have the ability to provide an educational and entertaining demonstration for any group. HHS operation on the FM LEO satellites is one of the best and most important tools we can use to expand our ranks.

Principle: FCC Part 97.1 (e) – “Continuation and extension of the amateur’s unique ability to enhance international goodwill.”



Patrick, WD9EWK, works satellite stations during a demo at the Scottsdale, AZ hamfest.



HHS Application: A vast majority of the FM LEO satellite passes I have worked provided a footprint that included portions of South America, Central America or Canada. Admittedly, this is not the same as being able to work that rare DX location on the HF bands, or even working into other parts of the world through amateur satellites in higher orbits that provide much larger footprints. However, being able to use a handheld station to make contacts with amateurs in other countries will demonstrate to anyone the international flavor of ham radio. Recently, I was talking to Rick, WA4NVM, who I first met on the FM LEO satellites. He was looking through some old QSL cards and found one from Cam, HP1AC, in Panama, for a satellite contact they had in 1980. That call sounded familiar, and I began looking through my old HF QSL cards. There he was – HP1AC – confirming a QRP contact we made in 1984 on 10 meters. Rick said that he'd looked up HP1AC on the QRZ Web site and sent an e-mail that Cam responded to. I did the same, and rekindled an acquaintance from almost 25 years ago. All of this – meeting Rick and developing a friendship with him, learning from him that HP1AC was still active, and contacting Cam after almost 25 years – happened because of my handheld satellite station. I am confident that many HHS operators have similar stories to share, and all of them relate directly to the international goodwill that is so important to all of us.

Conclusion

I am addicted to HHS operation on the Mode-J FM LEO satellites. That addiction is providing more enjoyment for me than anything I've ever done in ham radio. It also piqued my curiosity about using other modes (e.g., CW, SSB, digital) on other satellites. As a result, I have assembled a totally portable satellite station that can be fully battery powered to effectively work AO-7, AO-16, AO-51, FO-29, SO-50, VO-52 and the International Space Station FM repeater. I have confirmed contacts with stations via all of those satellites and the ISS using two Yaesu FT-817ND radios with a Diamond MX-72H duplexer, which allows me to operate a two-radio full-duplex station with the Elk 2M/440L5. I believe it's important to note that I continue to hand-hold the Elk, manually tracking all of the satellites, and manually tuning for Doppler. I prefer CW on AO-7, FO-29 and VO-52 because I find it easy to Doppler-tune more accurately

without computer assistance using CW.

I have resurrected and begun to refine skills for determining my location and a given satellite's position during a pass, and for making contacts in tough conditions (e.g., many stations competing for the same contacts and/or running very low power). I have discovered a mode and style of operation that not only addresses every principle outlined in FCC Part 97.1, but also lends itself beautifully to attracting and licensing new amateurs.

None of this would have happened without AMSAT. I encourage everyone to join the organization and support its efforts to keep Amateur Radio alive and well in orbit! New HHS operators should consider the AMSAT Web site as the online source for everything they need to make memorable contacts in orbit on every satellite pass they work.

Visit the AMSAT Web site today:

<http://www.amsat.org/>

My thanks to friends and fellow operators who reviewed this paper and provided input: Don Baughman, K7MX; Stew Haag, W4MO; John Henderson, N4NAB; Gould Smith, WA4SXM; and Rick Tillman, WA4NVM. Thanks, too, to Clint Bradford, K6LCS; Allen F. Mattis, N5AFV; and Patrick Stoddard, WD9EWK, for photos and graphics published in this paper.

Appendix A - Duracell Experiment Also please see next page for more detail.

SAT	CONTACTS	AVG ELEV	AVG RANGE
AO-51	32	37.878 DEG	1274.468 KM
AO-27	13	34.269 DEG	1452.774 KM
SO-50	6	30.850 DEG	1386.619 KM

Summary

Appendix B – Glossary of Terms

The following is not intended to be all-inclusive, but rather to highlight some of the terms used in this paper that amateurs encounter regularly in working satellites.

Terms related to finding and tracking satellites on a given pass:

- **AOS** – Acquisition of Signal. The point (usually expressed in time and azimuth position) that a satellite rises above the horizon in reference to an operator's location.
- **Maximum Elevation** – The point during a pass [usually expressed in time,

azimuth position and degrees (from 0 to 90)] at which a satellite has reached its highest point above the horizon in reference to an operator's location.

- **LOS** – Loss of Signal. The point (usually expressed in time and azimuth position) that a satellite descends below the horizon in reference to an operator's location.
- **Doppler Effect** – The shift in received frequency caused by a satellite's movement across the sky during a pass. From AOS to maximum elevation, the received frequency will drop from about 10 kHz above the center receive frequency to that center frequency. From maximum elevation to LOS, the frequency will drop from the center receive frequency to about 10 kHz below that frequency.

Other satellite-related terms:

- **AMSAT** – A nonprofit volunteer organization that designs, builds and operates experimental satellites and promotes space education. The organization works in partnership with government, industry, educational institutions and fellow Amateur Radio societies. AMSAT encourages technical and scientific innovation, and it promotes the training and development of skilled satellite and ground system designers and operators.
- **Crossband** – A mode of operation in which operators transmit on frequencies in one amateur band and receive on frequencies on a higher or lower amateur band (e.g., transmitting on 2 m and receiving on 70 cm).
- **Full Duplex** – A mode of crossband operation in which the receive frequency is not muted during transmission.
- **Mode J** – One of several transmit/receive configurations used in amateur satellite operation. Mode J features a VHF uplink in the 2 Meter amateur band and a UHF downlink in the 70 cm amateur band.
- **Polarization** – The orientation of the electric field generated by a radio transmission. Amateurs working satellites will encounter three types of polarization – Linear, Left Hand Circular and Right Hand Circular. HHS operators generally will be dealing with linear polarization at their stations. A



good example of linear polarization is the field generated by a vertical antenna, which radiates at a 90-degree angle away from the antenna. The angle of that antenna's mounting will determine the angle of radiation, or polarization, of the signal and the antenna.

- **Semi-Duplex** – A mode of crossband operation in which the receiver is muted during transmission.
- **UTC** – Universal Time, usually reported in 24-hour format. UTC also is known as Greenwich Mean Time (GMT).

Author's Note

This article includes references to the FM LEO satellite AO-27, which went silent on September 15, 2008. As of this writing, AO-27 has not returned to operation.

The author also notes that he purchased – at retail price – all of the equipment he describes using in this article. All recommendations included in the text are the results of the author's research and on-air experiences with the products. 📶



N3TL firing RF into the sky.

CALL	STATE	GRID	DATE	UTC	SATELLITE	ELEVATION	RANGE
KD8ILL*	WV	EM99	8-Jul	20:20	AO-27	78.4 DEG	819.627 KM
KD8ILL*	WV	EM99	8-Jul	20:23	SO-50	40.9 DEG	1018.977 KM
AJ5C	AR	EM36	8-Jul	20:24	SO-50	63.9 DEG	776.516 KM
K4DLG*	FL	EL97	9-Jul	0:04	AO-51	61.8 DEG	809.878 KM
W4TEJ	FL	EL98	9-Jul	0:04	AO-51	61.8 DEG	809.878 KM
VE3DRT	ON/CA	EN93	9-Jul	0:06	AO-51	52.5 DEG	883.771 KM
WA1DX	MA	FN42	9-Jul	0:07	AO-51	35.6 DEG	1132.152 KM
WA4NVM	TN	EM55	31-Jul	0:27	AO-51	39.6 DEG	1027.258 KM
N5ZNL	MS	EM42	31-Jul	0:29	AO-51	64.0 DEG	771.270 KM
W8KHP*	KY	EM79	31-Jul	0:30	AO-51	60.4 DEG	795.206 KM
KD0AR	OH	EN90	31-Jul	0:31	AO-51	42.0 DEG	994.244 KM
WB8LZG*	MI	EN72	31-Jul	12:38	AO-51	37.1 DEG	1207.110 KM
WA4NVM	TN	EM55	31-Jul	12:39	AO-51	57.8 DEG	922.106 KM
K4DLG*	FL	EL97	31-Jul	12:39	AO-51	57.8 DEG	922.106 KM
KB3MBO*	PA	FN21	31-Jul	12:41	AO-51	57.6 DEG	924.311 KM
K5MBV	TX	EM12	31-Jul	14:18	AO-51	14.9 DEG	2027.280 KM
KG7EZ	ID	DN32	31-Jul	14:49	SO-50	12.1 DEG	2036.632 KM
K5MBV	TX	EM12	31-Jul	14:52	SO-50	32.0 DEG	1183.810 KM
WA4NVM	TN	EM55	31-Jul	19:12	AO-27	20.2 DEG	1758.633 KM
KD8ILL*	WV	EM99	31-Jul	19:13	AO-27	26.2 DEG	1516.076 KM
W0SAT	IA	EN32	31-Jul	19:16	AO-27	31.9 DEG	1341.185 KM
WB2OQQ	NY	FN30	31-Jul	19:16	AO-27	31.9 DEG	1341.185 KM
KE5SR	TX	EL29	31-Jul	20:54	AO-27	25.1 DEG	1555.883 KM
YY6KWD	VZ/SA	FJ78	31-Jul	23:48	AO-51	36.2 DEG	1093.280 KM
WX8J	OH	EM89	1-Aug	12:00	AO-51	23.0 DEG	1638.277 KM
W4TEJ	FL	EL98	1-Aug	12:02	AO-51	22.8 DEG	1651.725 KM
W0TUP	ND	DN98	1-Aug	13:38	AO-51	31.0 DEG	1358.062 KM
WB9L	IN	EN61	1-Aug	13:40	AO-51	35.3 DEG	1255.504 KM
ND9M*	FL	EM70	1-Aug	13:42	AO-51	27.7 DEG	1470.268 KM
K5MBV	TX	EM12	1-Aug	13:43	AO-51	21.1 DEG	1729.322 KM
WA4NVM	TN	EM55	1-Aug	23:13	AO-51	15.2 DEG	1844.702 KM
WB9L	IN	EN61	1-Aug	23:13	AO-51	15.2 DEG	1844.702 KM
K0KN	KS	EM28	2-Aug	0:49	AO-51	37.1 DEG	1078.224 KM
W8KHP*	KY	EM79	2-Aug	0:51	AO-51	31.8 DEG	1198.746 KM
WA4NVM	TN	EM55	2-Aug	0:52	AO-51	24.0 DEG	1439.439 KM
WA4NVM	TN	EM55	2-Aug	3:51	SO-50	20.5 DEG	1530.982 KM
ND9M*	FL	EM70	2-Aug	12:59	AO-51	57.9 DEG	923.458 KM
WA4NVM	TN	EM55	2-Aug	14:38	AO-51	8.9 DEG	2450.183 KM
KC9ELU	IN	EM79	2-Aug	14:40	AO-51	8.6 DEG	2482.003 KM
KD0AR	OH	EN90	3-Aug	0:09	AO-51	70.9 DEG	740.738 KM
WB9L	IN	EN61	3-Aug	0:10	AO-51	78.8 DEG	717.516 KM
WA4NVM	TN	EM55	3-Aug	0:11	AO-51	67.1 DEG	760.209 KM
W1AW	CT	FN31	3-Aug	13:58	AO-51	20.6 DEG	1740.135 KM
XE1AO	MX/CA	DK89	3-Aug	14:42	SO-50	15.7 DEG	1772.798 KM
WA4NVM	TN	EM55	3-Aug	19:31	AO-27	42.0 DEG	1120.866 KM
K4YZI*	AL	EM63	3-Aug	19:32	AO-27	33.1 DEG	1309.628 KM
WA2S*	NJ	FN20	3-Aug	19:32	AO-27	33.1 DEG	1309.628 KM
KB1JAE	NY	FN03	3-Aug	19:33	AO-27	24.1 DEG	1592.870 KM
WB9L	IN	EN61	3-Aug	19:33	AO-27	24.1 DEG	1592.870 KM
WA8SME	CT	FN31	5-Aug	18:32	AO-27	11.6 DEG	2251.175 KM
K4DLG*	FL	EL97	6-Aug	19:44	AO-27	63.8 DEG	876.440 KM

* Two-way HHS contact

NOTE: Contacts are grouped by satellite pass

A Simple but Effective Relay Driver for 24 or 28 Volt Relays

By Chuck Steer, WA3IAC, wa3iac@arrl.org

[Editor's Note: Chuck's paper was originally published in the Proceedings of the 2006 Microwave Update Conference in Dayton, Ohio. His design will be useful for terrestrial and satellite antenna switching requirements. Permission to reprint granted by the author and ARRL who published the Proceedings book.]

Over the years I have found that surplus relays can be a bargain whether you find them on e-Bay™ or at a local hamfest. Finding a 28 volt supply to drive them is another story. If you want to add a relay inside of a transverter you soon find that the power supply will be considerably larger than the relay it has to power. In the "shack" this may not pose a problem, but when roving or going portable finding 115 VAC to provide the 28 volts needed to power the relays is even harder and can be costly if you choose an inverter. The lower cost alternative is to have a small, cheap and dependable 28 volt supply.

For some years now I have used a small circuit board (0.80 x 1.3 inch) that requires +12 to +13.7 volts in (+18 volts max.) and will produce 22 to 25.4 volts output. That voltage is enough to drive any 24 to 28 volt relay. Prototyping board was used in my earlier layouts, but in the past three years I

had some printed circuit boards made that make the layout more uniform.

The heart of the relay driver is the TC962cpa from Microchip. For this application the device is used as a positive voltage multiplier. The TC962 is an advanced version of the industry standard TC7662 high voltage DC-to-DC converter. Using improved design techniques and CMOS construction the TC962 can source as much as 80mA versus the 7662's 20mA capability. The TC962 is compatible with the LTC1044, SI7661 (not tried) and the ICL7662, and comes in an 8-pin dip package. A complete data sheet can be found on the Web. [1]

Referring to the schematic in Figure 1, when +12 volts is applied to the input, +22 volts will be applied to the relay at the output pins (+12 x 2 - 2 = 22). The two volt drop is due to the diodes and the chip. With 13.5 volts applied to the input, 25 volts will be applied to the relay. Either the TC962cpa or ICL7662cpa device can be used without modification to the circuit board. Diodes D1 and D2 can be anything from the 1N4001 to 1N4007 types. Capacitors C1 and C2 are 10uF at 50 volts, but I found that sometimes 63 volt capacitors are a little cheaper and will fit in the PC board. I have used tantalum capacitors, but found that

aluminum radial-leaded capacitors seem work just as well; at least in the short term. All the parts are available from any number of parts distributors (Digi-Key part numbers are given). Figure 2 shows a completed board assembly, 0.8 x 1.3 x 0.060 inches. Total parts cost should be less than \$4.00 plus the PCB.

A complete kit is available from the author. [2]

Author's biography: Chuck holds an Amateur Extra class license and was first licensed in 1964. He is active on 50 through 1296 MHz and in the past has worked all bands 160-10M. Chuck is an RF designer at AR Worldwide (formerly Amplifier Research, Inc).

Footnotes

- [1] Microchip data sheet at: <http://rocky.digikey.com/WebLib/Microchip/Web%20Data/TC962.pdf>
- [2] For a complete kit contact Chuck Steer, chuckwa3iac@yahoo.com ☎

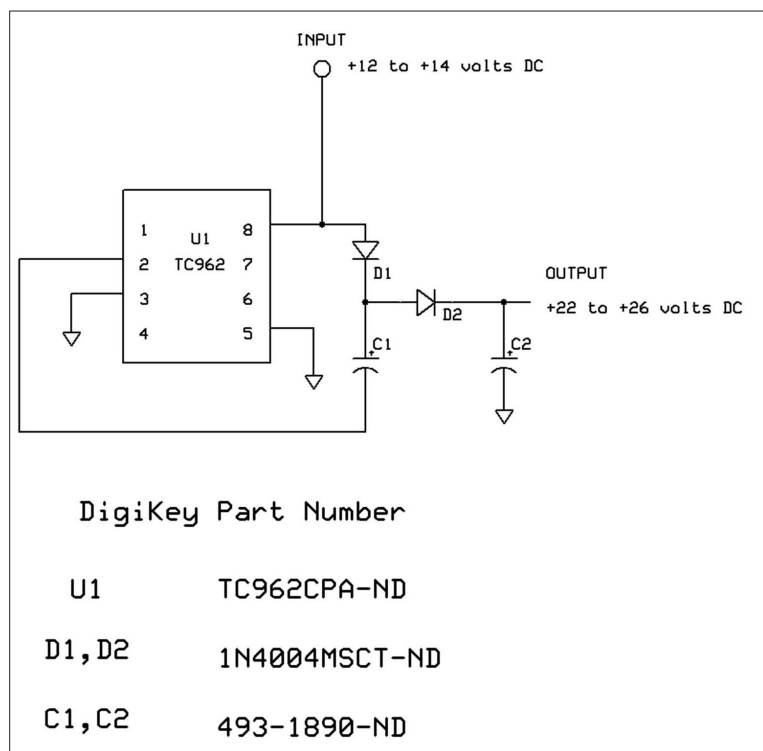


Figure 1: Circuit schematic.

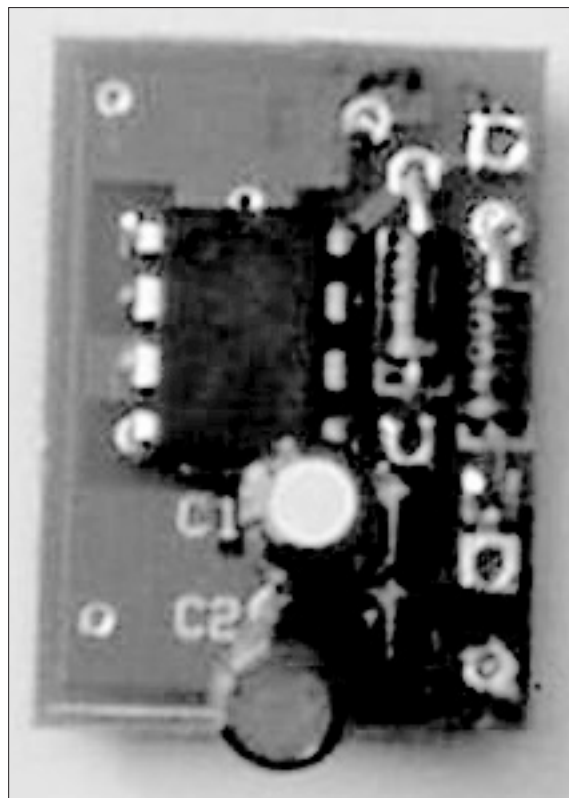


Figure 2: Circuit board assembly.



Release for AMSAT on June 15, 2008: CFC Certification 2008

On June 13, 2008 the The Office of Combined Federal Campaign Operations issued the final draft of the listings for independent organizations that have been approved for participation in the 2008 CFC. The Radio Amateur Satellite Corporation (AMSAT) was again included in the approvals.

The CFC, or Combined Federal Campaign, is the U.S. Government equivalent of the United Way in the private sector. The campaign affords all US Government employees the opportunity to make donations from their regular paychecks to CFC approved charities. AMSAT has again successfully applied to CFC for that status and is grateful for the approval. This stamp of approval means that AMSAT has met the strict standards set by the U.S. Office of Personnel Management (OPM) assuring donors that our programs of work and financial operational standards meet the standards for expectable operations and programs.

Those AMSAT supporters who wish to make payroll contributions should select the Radio Amateur Satellite Corporation (AMSAT) during their campaign this coming fall. The AMSAT CFC Charity number is 10158. Payroll deduction is a simple, convenient way to support your AMSAT.

Gunther Meisse, W8GSM
Treasurer
AMSAT North America



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a tracking program designed for ham satellite applications.
For Windows 95, 98, NT, ME, 2000, XP, Vista.

Version 12.8 has improved Windows Vista compatibility and enhanced support for tuning multiple radios.

Version 12.8 Features:

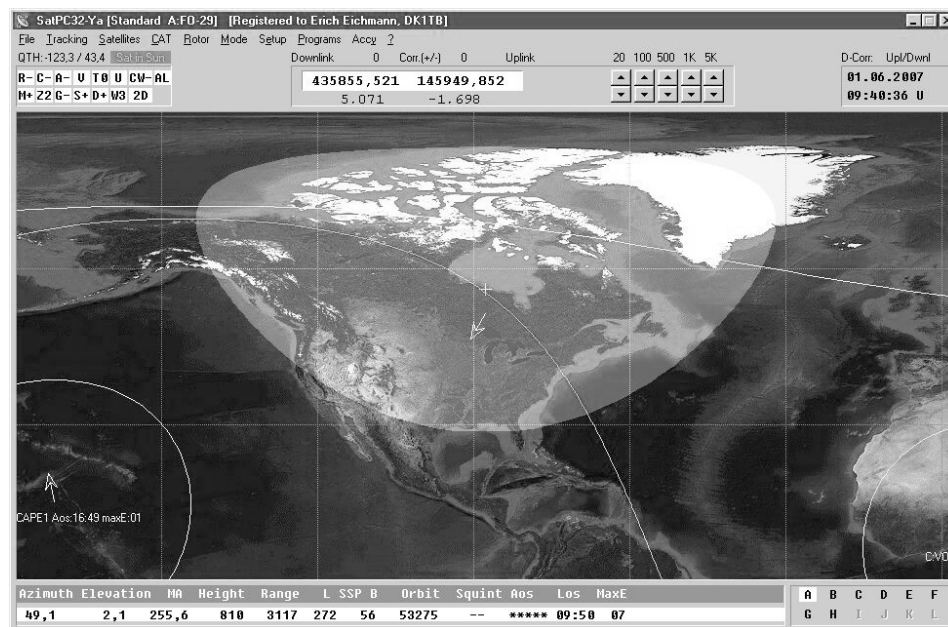
- Select 2D/3D map with a single mouse click
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The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.





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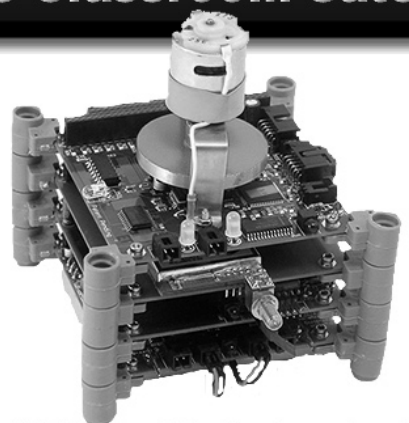
- 1) Bare board - \$20 + S&H - no parts kits available
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Documentation for the LVB Tracker can be found at: <http://www.LVBTracker.com>

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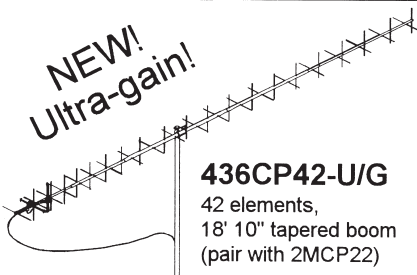
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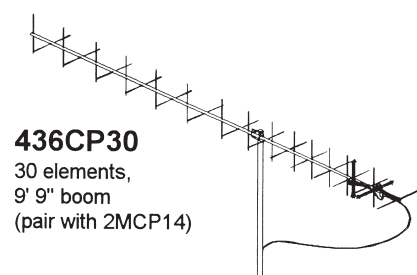
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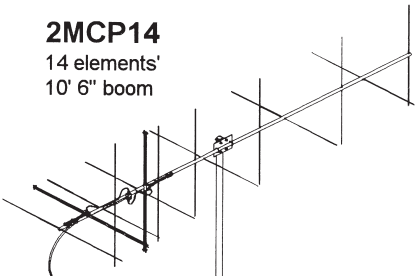
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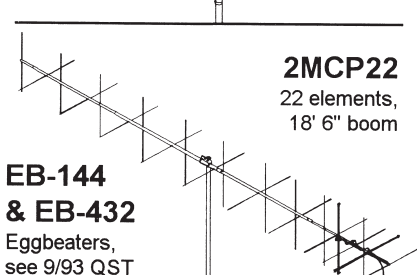
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42 elements,
18' 10" tapered boom
(pair with 2MCP22)



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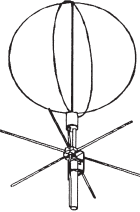


2MCP14
14 elements'
10' 6" boom



2MCP22
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Successful Ground Station Installation at the International Space University in Strasbourg, France

by Graham Shirville, G3VZV, g3vzv@amsat.org

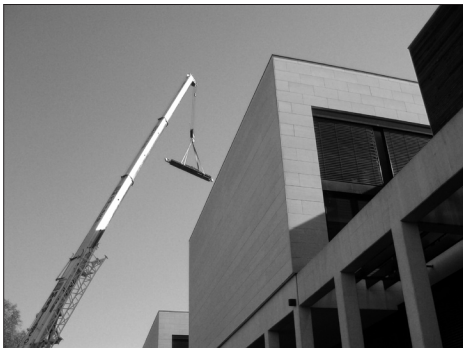
As part of the AMSAT-UK involvement with ESA in the development of GENSO, The Global Education Network for Satellite Operations, we had agreed to assist with the installation of two "reference" ground stations. These "reference" stations are intended to demonstrate the system using the best hardware available within a budget which, whilst beyond the budget of most amateurs, is, by a factor of more than 10, well below the costs normally associated with ground stations in the professional/corporate world. In fact the antennas, radio and shack equipment is almost exactly as many amateurs use. Only the rotator system itself



A view of the ISU building before our antennas were erected.

is extra robust to cope with extreme weather conditions and the almost constant usage tracking many satellites on a 24/7 basis.

As the GENSO software is, itself, still being developed by a number of student teams, it is expected that the reference stations will also be used during the development process as part of the Alpha and Beta testing phases. The first station was intended to be installed at the ESA ESTEC facility in the Netherlands but it has, so far, proven to be difficult to find a satisfactory location for the equipment and antennas within the complex.



Part of the antenna base frame being craned onto the roof.

Therefore, in late June 2008 it was decided to go ahead with the installation of a station at the ISU. The International Space University provides graduate-level training to the future leaders of the emerging global space community at its Central Campus in



Unpacking and assembling the antennas in the main hall in front of an Ariane rocket motor.

Strasbourg, France, and at locations around the world. In its two-month summer session and one-year masters program, ISU offers its students a unique core curriculum covering all disciplines related to space programs and enterprises – space science, space engineering, systems engineering, space policy and law, business and management and space and society. The university starts a new semester on Sept 1st every year and it was decided that the station should be ready for a grand opening to coincide with the ceremony!



The VHF arrays waiting to be craned onto the roof.

Working as volunteers, Jim Heck, G3WGM, and John Rivett, M3RRX, quickly made an initial visit to survey the proposed location for the station, the roof for the antennas and the route for the vital coax and other cables to run between the two.

While the ISU staff and consultants were



The antenna array almost completed.

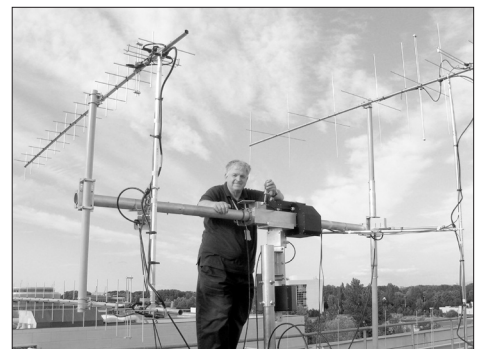
busy sorting out the correct frame and grid on the roof that would be required to support the antennas, the actual antennas, rotator and pedestal assembly were shipped down from ESTEC where they had been delivered by M2 Antenna Systems Inc earlier in the year.

Then there was a short pause in the program whilst we all, especially Jim, became involved



Wiring the polarization switches and trying to fish for a missing washer beneath the grid.

with the organization and enjoyment of the AMSAT-UK Colloquium at the end of July. Immediately after the dust of that event had settled, John returned to ISU to commence the assembly of all the antenna arrays, their mounting on the pedestal, the craning of

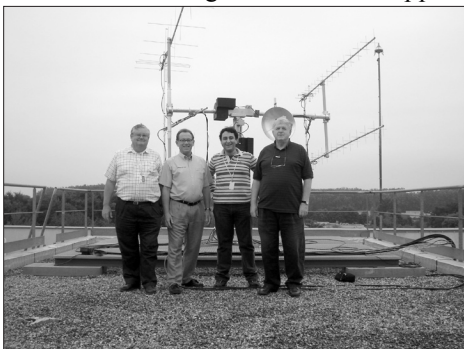


M3RRX making adjustments to the elevation rotator.



Arty shot of the antennas.

the whole assembly up three floors onto the roof and the installation of all the cables. The photos show the amount of work that was involved in the correct assembly of all the pieces of metal and wires and the successful craning of the main support



The team on the roof. From the left: Jim, G3WGM; Graham, G3VZV; Viktor, PE1VN; John, M3RRX.

grid, pedestal and each antenna array onto the roof. Luckily he had the assistance of a number of ISU staff members and also from Viktor Nikolaidis, PE1VN. Viktor completed his masters degree last year at the University of Surrey Space Science Centre and was part of the team who built and installed a ground station there. He is now working at ESA ESTEC as a Young Graduate Trainee, with GENSO being one of his prime responsibilities.

This work was completed successfully around middle of August but it was only



Routing the cables through the building.

about then that the rest of the required hardware could be ordered. Amazingly Jim was able to procure pretty well everything, within a week, and get it shipped to ESTEC from where half of the quantities were further shipped onto the ISU. Luckily it arrived in time for the main installation team of Jim, John, Viktor and myself to start work first thing on Monday 25th August.



PE1VN and G3WGM installing the GSS computers.

A quick review showed that on the roof, the antennas looked good, although the S band dish and cables still had to be installed together with the roof camera.



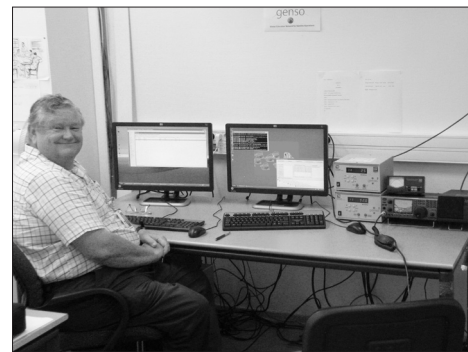
Three computers and one radio.

In the shack the promised power and data connections still had to be finished off but this work was soon completed. It did then take some considerable time though to successfully configure our sub network within the main ISU system to ensure that the GENSO teams have the correct remote access without compromising the university's network security.

In parallel with this work, the IC910 radio, the 9162 TNC, the power supplies, polarization switch, the rotator controllers and other sundry items were all assembled together and given a full test to satisfy the requirements of the functional test and acceptance criteria that had been laid down.

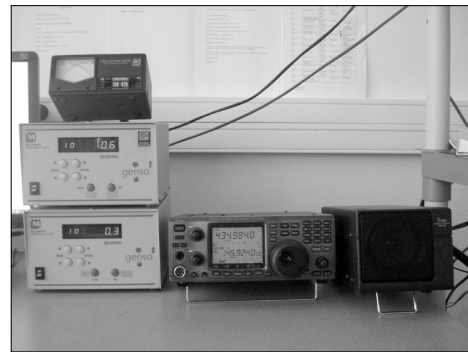
As might be expected not everything went according to plan. As well as the Internet

challenges, the rotator initially wanted to go down when we pushed the up button and was also reluctant to accept commands from any computer program. However by quite late on Tuesday evening we had the ground station computer successfully communicating with the radio, TNC and rotator controller and we successfully tracked some satellite passes including enormous signals from the S band transmitter on AO51 which had been very kindly switched on at short notice by the command team.



G3WGM proudly admiring the station.

On Wednesday, working remotely with the software member of our team, Dave Johnson, G4DPZ, who was back in the UK, we were able to load the actual GENSO GSS (Ground Station Server) software and, after a few false starts, had it tuning the radio and driving the rotators. We had a quick QSO on AO51 with John, KD6PAG, who was operating QRP (140 milliwatts) portable in Scotland. We then did some clearing up and started tidying up the cables around the antenna system. The reward was an early finish around 6 PM and to be taken for dinner in a square in the centre of the beautiful old city of Strasbourg hosted by the dean of the university.



Closeup of radio and rotor controller.

We were scheduled to finish on Thursday 28th August in the morning and agreed to provide a short presentation to the dean, some

continued on next page (bottom) ...

Like Father, Like Son – W5KWQ Celebrates W5LFL with 10-Day Operation on the ISS

by Timothy J. Lilley, N3TL, n3tl@amsat.org

A few hours after arriving in orbit, docking with the International Space Station and transferring to the ISS from the Russian Soyuz TMA-13 spacecraft that carried him into space, American Richard Garriott, W5KWQ, fired up the ISS “shack” and started following in his father’s footsteps.

Almost 25 years earlier (from Nov. 28 to Dec. 8, 1983), Richard’s father, Owen Garriott, W5LFL, became the first Amateur Radio operator in space when he transmitted during the STS-9/Spacelab 1 mission. The elder Garriott made more than 350 two-way contacts and prompted more than 10,000 SWL reception reports (mine among them!) during that first “orbital DXpedition.”

Before getting into Richard’s historic amateur operation from the ISS, here are some facts about his father’s operation from the SWL QSL card I received confirming my reception report.

W5LFL’s STS-9/Spacelab 1 station included a modified Motorola MX-300 2 m FM transceiver (output 4.5 watts) hand-built by the Motorola Amateur Radio Club in Florida, and a directional antenna (a ring-radiator

with cavity) designed to fit in the upper window of the spacecraft. Lockheed employees volunteered their time to build the antenna for NASA.

In approximately 4 ½ hours of operation during slightly more than 20 orbits, W5LFL transmitted in FM and CW (by keying the carrier) and tape-recorded all transmit and receive audio, which constituted the station log. Amateurs in 23 countries either made contact with or submitted an SWL report for the W5LFL operation.

Now ... fast-forward to October 2008. During his 10 days aboard the ISS, Richard, W5KWQ, made more than 500 voice contacts and transmitted more than 1,000 Slow Scan TV (SSTV) images using the ISS’ Kenwood D700 transceiver and linear antenna mounted outside the ISS. Richard used a Kenwood VC-H1 camera – new to the ISS – for a majority of his SSTV transmission. However, he did make some SSTV transmissions using ISS’ software-based system and either SpaceCam or MMSSTV software.

You can still see hundreds of Richard’s SSTV images on the Web at: <http://www.>



No, these are NOT the latest amateur satellites in operation! Astronauts Greg Chamitoff, KD5PKZ (left), and Mike Fincke, KE5AIT (ISS Expedition 18 Commander), float around the ISS’ Harmony node with Richard Garriott, W5KWQ, with three Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) in this Oct. 22, 2008, photograph. NASA photo.

faculty members and some students at 0950. This was carefully timed to coincide with another good pass of AO51 at 09:56. The demonstration of the strong signal appearing out of the noise exactly as shown on the Nova map impressed us as well as the audience and a good solid QSO was immediately made with a station in Norway!

So there is now a fine station to help the GENSO project develop into the beta stage during 2009 when it will be possible for

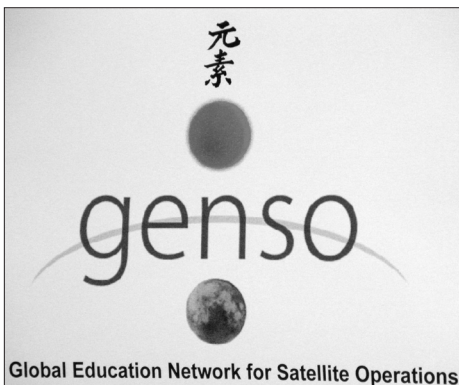
other universities and individual amateurs to join in. It will also be available to demonstrate Amateur Radio and amateur satellite operation to the many masters students that pass through the university each year – many of whom will go on to become important members of the space profession in the years to come.

In addition, the volunteer team involved had a great time putting the station together and testing it out and of course learned a lot in

the process – a great result!

I would like to thank Jim especially for all the work he put into obtaining the hardware and getting it despatched in such a short time, John for spending many hours/days at ISU ensuring that the antenna construction and installation proceeded smoothly and safely and Viktor for his coordination efforts and his hard work on site.

Pictures from the roof camera can be viewed at <http://193.51.107.114>



**Global Education Network for Satellite Operations
The sign on the door.**



ISU Building with GENSO antennas on roof



No Guinness but a nice lager.

"On my recent flight, I had the great opportunity to speak directly with and trade call signs with hundreds of hams around the globe," Richard said in a statement transcribed and delivered by his father shortly after Richard landed in Kazakhstan on Oct. 24. "For me, it was an unexpected joy to find so many enthusiastic hams that were so well informed and interested in my activities in orbit. When I began my transmissions with preplanned SSTV images including test patterns and family images, I did not know how they would be received. But it seemed that fellow hams really

enjoyed seeing this beginning to my time on the International Space Station. Throughout the bulk of my 10 days on the ISS, I tried to be speaking by voice or transmitting SSTV images whenever possible."

In addition to providing amateurs worldwide with an opportunity to help him commemorate his father's historic ham radio operation a quarter-century earlier, Richard also participated in more than a dozen school contacts with youngsters around the globe during his stay on the ISS.

In an October 15, 2008 update to the amateur community, AMSAT-North America Vice President for Human Spaceflight Operations



Sulaiman, 7Z1SJ, received this SSTV image of Richard Garriott on board the ISS during his 10-day mission. This is one of the many images uploaded to a special Web site created for amateurs to share their SSTV images.

and ARISS International Chairman, Frank Bauer, KA4HDO, brought the significance of this operation into quick focus.

"You are witnessing and are a part of history," Bauer said. "Some of you have asked why Richard is using his callsign for some QSOs and SSTV contacts instead of the ISS station callsigns. There is a long and proud history that is attached to the Garriotts. This includes ham radio in space and their personal callsigns. Twenty five years ago, Richard's father, Owen Garriott, W5LFL, initiated the first ham radio contacts from space on the STS-9 SAREX mission. Richard, W5KWQ, is following in his father's footsteps, using the ARISS ham radio system extensively

continued on page 21 ...

The AMSAT Store (see www.amsat.org) is back online! Here is a new AMSAT product.

AMSAT 10' locking carpenter's tape \$5



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- Specific area Web site information maintenance
- Video recording, digital conversion and editing
- Write technical or instructional material
- Educational activities
- Promoting AMSAT as an Area Coordinator



and any other area you think you think you can make a difference.

We often have people volunteer, but many don't deliver on their promises. So, pick an area that you think needs improvement and explain what you will do to make it better. Then do something to show that you can follow through.

Send your suggestions, actions plans and a description of why you are capable of doing this task to Gould Smith, WA4SXM, wa4sxm@amsat.org

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THANK YOU!



AMSAT-NA's Engineering Task Force

Bill Ress, N6GHZ, AMSAT-NA Alternate Board Member

It's no secret that 2008 was a troubling time for AMSAT-NA satellite engineering efforts. It has been characterized by several AMSAT board members and senior officers that the engineering activities "imploded", having lost our Vice President of Engineering, Bob McGwier, and many of the engineering volunteers working on the Eagle project. As a member of the Eagle design team, I went through that unfortunate period and it was one of the factors that prompted me to make a run for the board, thinking AMSAT had to do better. So with that unpleasant experience behind us, where is AMSAT engineering today and what does the future look like?

In August 2008, The AMSAT board and senior management held a "soul searching strategy" meeting in Baltimore. Many topics were on the table, including ideas for reorganizing AMSAT engineering, revising the AMSAT Mission Vision statement and a re-assessment of the Intelsat rideshare.

Also proposed at that meeting was the idea of AMSAT starting a "module" development concept of key satellite functional subsystems, which could be modified to fit any appropriate launch opportunity for either LEO (low earth orbit) or HEO (high earth orbit) satellites.

As a result of the Baltimore meeting, many of these ideas were refined and discussed at the AMSAT October 2008 board meeting in Atlanta. The key engineering related decisions reached by the Board were:

- The AMSAT Mission Vision was revised to include the pursuit of all launch opportunities, not just HEO.
- The search for a Vice President of Engineering will continue. That search continues today.
- The module development concept was accepted.
- An Engineering Task Force would be put in place to evaluate the rideshare geostationary satellite concept proposed by Tom Clark, K3IO, develop a modularization strategy, create interface specification and engineering standards and to propose an engineering budget for 2009.

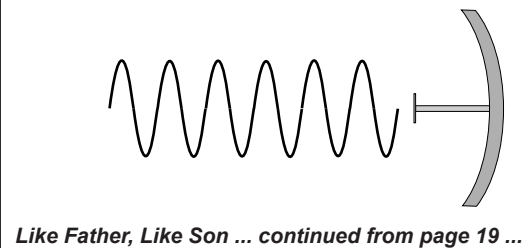
These decisions are highlighted in the State of AMSAT report given by AMSAT

President Barry Baines, WD4ASW, at the 2008 AMSAT Symposium in Atlanta, October 2008. Barry's report may be downloaded from the AMSAT Web site.

The engineering task force members include Drew Glasbrenner, KO4MA, Tony Monteiro, AA2TX, Lou McFadin, W5DID, Tom Clark, K3IO and myself, Bill Ress, N6GHZ, as Chair. Starting in November 2008, the team has been holding bi-weekly teleconferences.

The initial focus has been the review of Tom Clark's rideshare proposal. While Tom's proposal is for a 3.4/5.8 GHz transponder, the feasibility of adding conventional linear transponders utilizing combinations of bands from 145 to 2400 MHz was also discussed. Additionally, we have determined that we have enough information to start formalizing the modularization concept, which is also applicable to the rideshare proposal and this will be the focus of subsequent discussions. We will identify, specify and prioritize the modules needed with the desire to start engineering design activities on them in 2009.

While the team has a lot on the table, the dynamic makeup of the group is permitting good discussions and progress. I'm confident that that we can contribute to the effort to keep AMSAT engineering activities moving forward. I will be reporting on our activities in subsequent Journal issues and I encourage you to contact me with your thoughts and suggestions at n6ghz@amsat.org.



Like Father, Like Son ... continued from page 19 ...

on his first flight. And Richard's callsign is actually his grandfather's original callsign. So you can see that this mission touches three generations of ham radio and two generations of ham radio in space!"

Few Amateur Radio operations since the W5LFL mission have generated so much interest and participation.

"After my first 100 or so QSOs, I understood how well 'networked' the global ham community really is," Richard said. "I received specific reports back through Mission Control-Moscow about technical aspects of my work and how the community was enjoying the transmissions. This redoubled my enthusiasm to do quality work for the Amateur Radio legions around the world as I realized how much it meant to those with whom I had the chance to talk."

"By late in my flight I had contacted many hundreds of hams by voice and I have good records of these contacts" he added. "Finally, I sent some 'Goodbye' images on my last day in space. I also contacted many hams that had listened to or contacted my father from space 25 years ago. Some hams I contacted 2 to 4 times on my flight."

Those goodbye images elicited heartfelt responses from the world's amateur community.

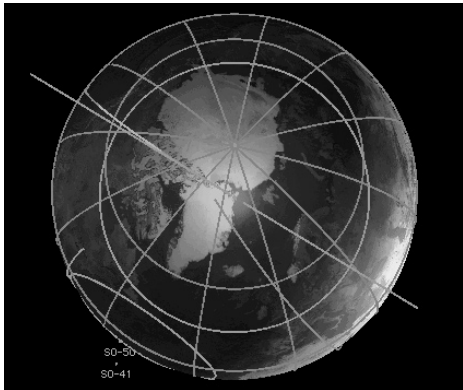
"On those last days, I was very moved when sent many 'soft landing' messages from individuals and classrooms full of children as I passed by," Richard said. "The ham community has added greatly to my personal feelings of success on my flight. I can only hope that you enjoyed it as much as I did."

QSL cards are in the works for those who had QSOs with Richard during his operation. They are available through the normal ARISS process. See www.ARISS.org for full details.

At left: Owen Garriott, W5LFL, speaks to reporters with his son, Richard, W5KWQ, on Oct. 8, 2008, outside the Cosmonaut Hotel crew quarters in Baikonur, Kazakhstan. The Garriotts represent two generations of ham radio in space and three generations of amateur operation (Richard's callsign also is his grandfather's original callsign). NASA/Victor Zelentsov photo.

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AMSAT Eagle – Building a Mission for Education

JoAnne Maenpaa, K9JKM, k9jkm@amsat.org

Part One – A geostationary Amateur Radio satellite will give educators an out of this world opportunity to bring space communications into the classroom. To be able to launch AMSAT-Eagle we need to excite potential funding sources. Here, in Part One of a series of four articles [1], (Footnotes are at the end of the article – Ed.) we will examine how Eagle will drive the exciting potential for the future of Amateur Radio in space and education.

Introduction

Traditional Amateur Radio has found application in classroom education by allowing the teacher to introduce topics in science, mathematics and social studies with fun and interesting methods. One of the most visible applications of Amateur Radio in education is the highly successful Amateur Radio on the International Space Station Project (ARISS) which connects students with the astronauts via ham radio.

The second path of education in Amateur Radio involves our own community of radio operators. We continually learn about electronic theory, communications methods, technology and radio law first to earn our Amateur Radio license. Being a curious group of people, most hams have embarked on a journey of self-directed lifetime

learning.

The proposed GEO-Eagle satellite offers Radio Amateurs the opportunity to teach and learn on an ongoing on-demand basis with our own Learning Channel in Space.

The AMSAT Eagle Advanced Communications Package

AMSAT-NA's engineering team has decided to take a dual approach to the mission concept of the Phase 3 Eagle Satellite development project. The original approach of a high-earth orbit (HEO) mission has been expanded to also include the possibility of a ride-sharing mission attached to a geostationary communications satellite. The Eagle communications payloads apply equally well to either mission and the entire package is being developed to be ready for the first opportunity – HEO or GEO – that becomes available. One of the primary payloads aboard either the HEO or GEO Eagle mission is planned to include the Advanced Communications Package.

The AMSAT Eagle design team is proposing a communications payload that utilizes the amateur microwave allocations. With Tom Clark, K3IO's "strawman" design [2], the digital ACP channels would also be accompanied by some more conventional "bent pipe" linear transponder channels.

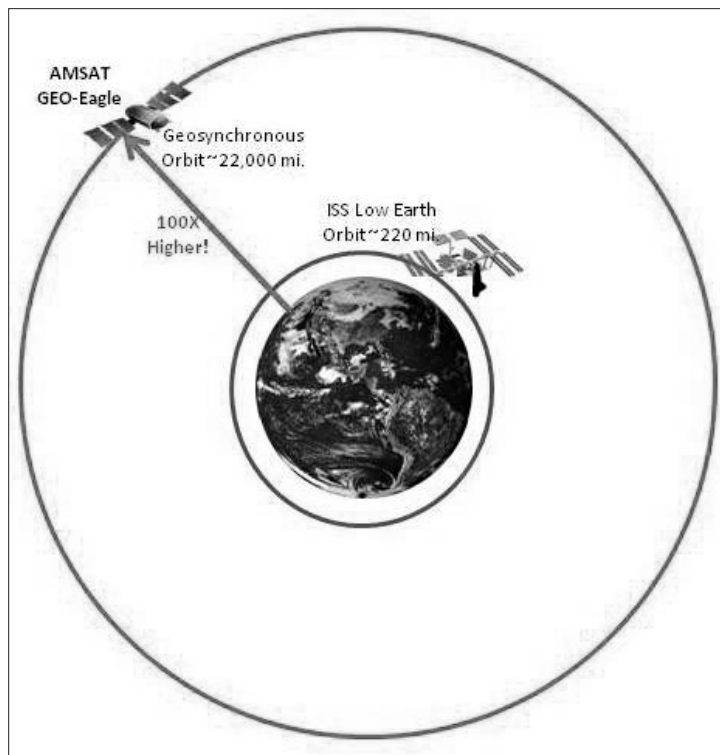


Figure 1: A Geosynchronous Orbit will fly Eagle 100X higher than LEO.

Realizing that microwave earth station design is beyond the scope of most hams the Eagle team is considering options to make an ACP-capable earth station within reach of most radio amateurs. The design work is still ongoing, but it has been proposed that the earth station may be distributed along the lines of the project budgets are being designed so the average earth station can leverage the use

of 0.9 – 1.0 meter diameter dishes (36 – 40 inches) and would appear similar to installations used for home satellite television.

A rideshare opportunity for the Eagle ACP means that AMSAT would be allowed to attach its radio payloads to a geostationary communications satellite. The "mother ship" would provide hundreds of watts of DC power over a span of 10 to 15 years. The main satellite would also perform all station keeping and earth pointing navigational duties for keeping high gain antennas pointed at earth. For the amateur operator on earth within the satellite's footprint, it means that no tracking will be required once the signal is acquired. You will be able to aim your antenna at a predictable, fixed point in the sky.

Launch opportunities under study will place the Amateur Radio payload over the equator, offering 365/24/7 amateur satellite availability for stations within the 11,000 mile wide footprint on the earth below. Future geostationary rideshare opportunities over the upcoming years will allow AMSAT to expand the Eagle constellation to provide 365/24/7 worldwide amateur satellite coverage with additional satellites spaced along Earth's equator. Exciting times are ahead for Amateur Radio in space!

Refer to Figure 1 to compare the differences between Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO).

Once AMSAT achieves GEO orbit we will be 100 times higher above the earth than a LEO orbit. Everyone is certainly looking forward to the increase in communications range because of the increase subsatellite footprint.

Figure 1 is not drawn to scale because of page size limits. Imagine that the LEO orbit shown is 1/8 inch or 0.125 inch. If drawn to scale, a 100X increase in orbit would be at 12.5 inches away – off the page!

ARISS Brings Amateur Radio in Space Down to Earth and Into Your School

The 10-Minute LEO Direct Contact Limitation

One of the main features of the Amateur Radio on the International Space Station Project (ARISS) has been to enable direct contacts between the on-orbit crew and the students. The 220 mile high orbit of the ISS



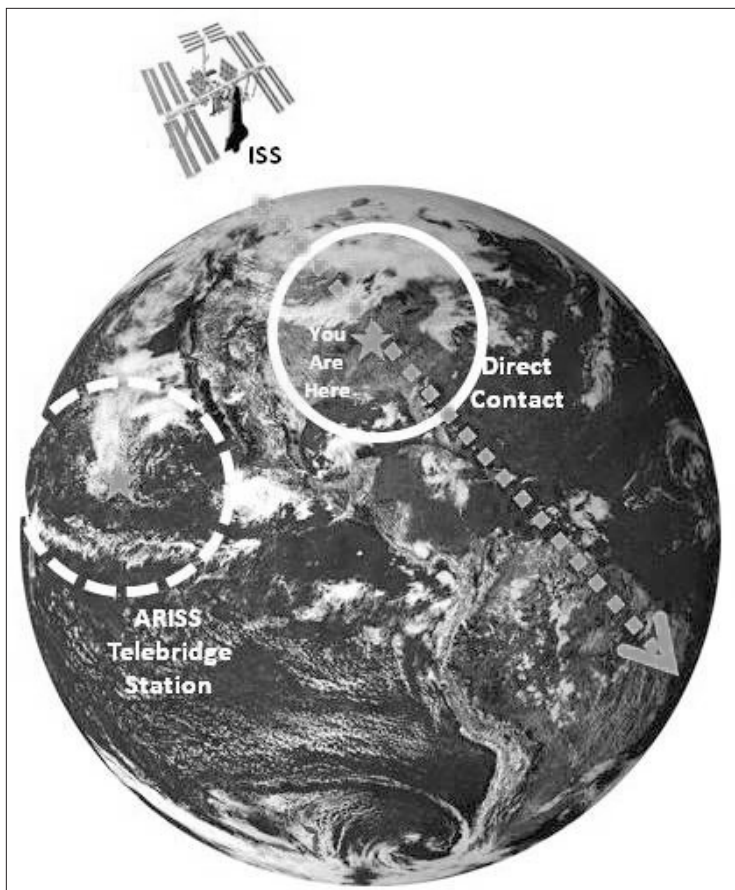


Figure 2: A direct contact with ISS is only 10 minutes for everyone.

gives the crew a view of about 2000 miles in diameter. ARISS Amateur Radio contacts use frequencies around 146 MHz and 437 MHz which means that the maximum range of these line-of-sight radio waves is also limited to a circle 2000 miles in diameter. You can only make a direct contact with the ISS when your earth station is within its subsatellite footprint – the amount of earth visible.

Given the height of the orbit and the orbital velocity of 17,500 miles per hour the maximum time available to make a direct contact with the ISS is 10 minutes. Then, ready or not – they are gone!

Using the example shown in Figure 2 you will be able to talk to the ISS crew only as long your earth station is within its radio footprint. This is shown as the white circle approximately 2000 miles in diameter. The coverage circle “moves” across the surface of the earth at 5 miles per second.

Alternatively, when a school ARISS contact needs to be conducted when the ISS is not within range a telebridge station is used to provide the radio link and the audio is relayed via telephone line to the students. This allows additional contact opportunities with the ISS but the telebridge station is also

ARISS contact, could be connected via a telephone conference circuit. To free ARISS contacts from the limitation of a single telephone circuit, Figure 3 illustrates how the GEO-Eagle can be used to provide extended ARISS coverage via telebridge-handover. The only thing required would be that both the telebridge stations and the school be within the 11,000 mile wide footprint achievable from geostationary orbit.

The telebridge station (or your school station) would be busy tracking the low-orbit ISS but your radio link to the GEO-Eagle satellite will be remain

facing that same 10 minute time limit.

GEO-Eagle Enables 30-Minute ARISS Contact

Longer continuous contact with the ISS can be maintained if there are enough adjacent telebridge stations. During this phase the ARISS ground stations will continue to maintain contact with the ISS using the established methods, i.e.: 145.800 MHz. This way each telebridge station can hand off to the next station as the subsatellite footprint moves out of range. Each of the telebridge stations, along with the target school for the

stationary. As many stations as needed to help complete the contact (or those interested in listening in) only have need to aim their Eagle earth station at the satellite when initially configuring your station.

The current generation of Amateur Radio transceivers used on earth and the ISS limit communications modes to those which fit into an audio pass band. Voice communications, slow-scan television pictures and 1200 baud data traffic are examples of what is currently done. The Advanced Communications Package on Eagle will provide multi-media access depending on the capability of the ground station. Low rate data, voice, and video are planned to be available to users.

The Future: GEO-Eagle Constellation Enables Continuous ARISS Coverage

AMSAT plans to grow its geostationary constellation to provide full-earth coverage. This requires at least three satellites. Once completed, Amateur Radio operators and school programs will have continuous contact with an Eagle-tracking ARISS Amateur Radio station aboard the ISS. This will provide schools with TDRSS-like [3] capability allowing whole-orbit access to space based scientific experiments from

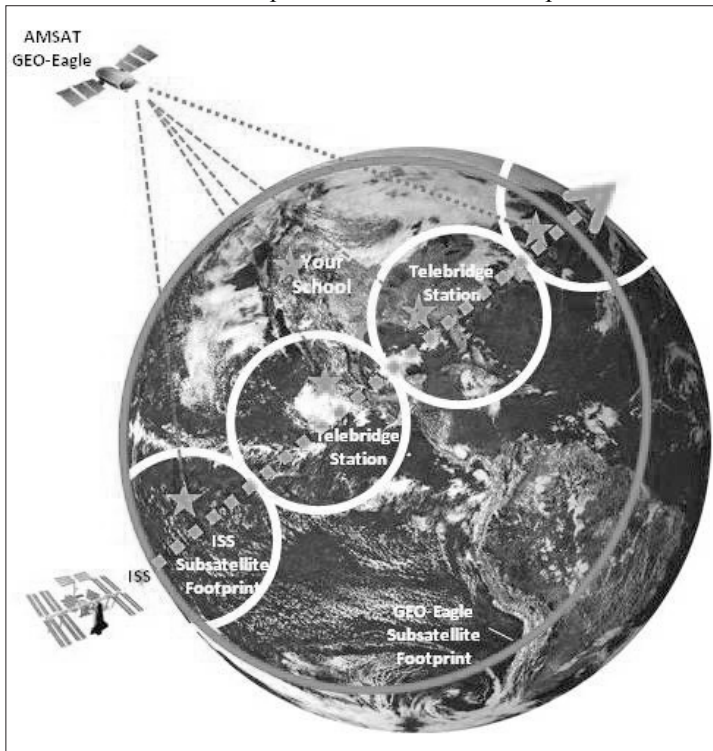


Figure 3: GEO Eagle links multiple ARISS Telebridge stations with their 10 minute window and the target school. Handover capability provides up to 30 minutes of contact time with the students. The Eagle ACP provides voice, data, and video.

continued on page 26 ...

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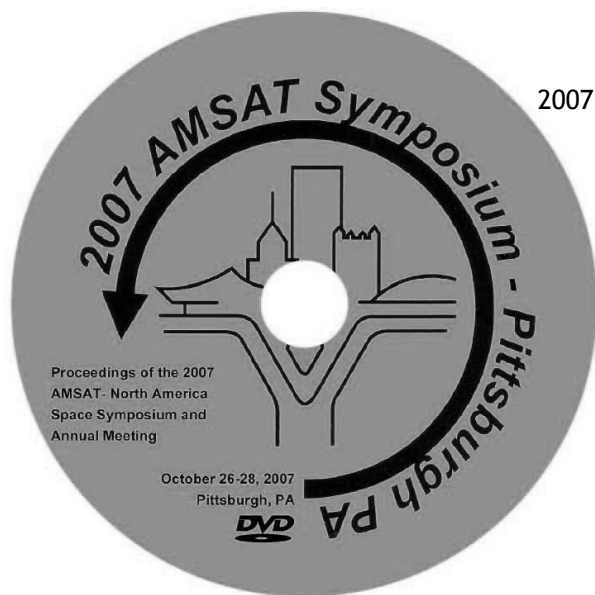
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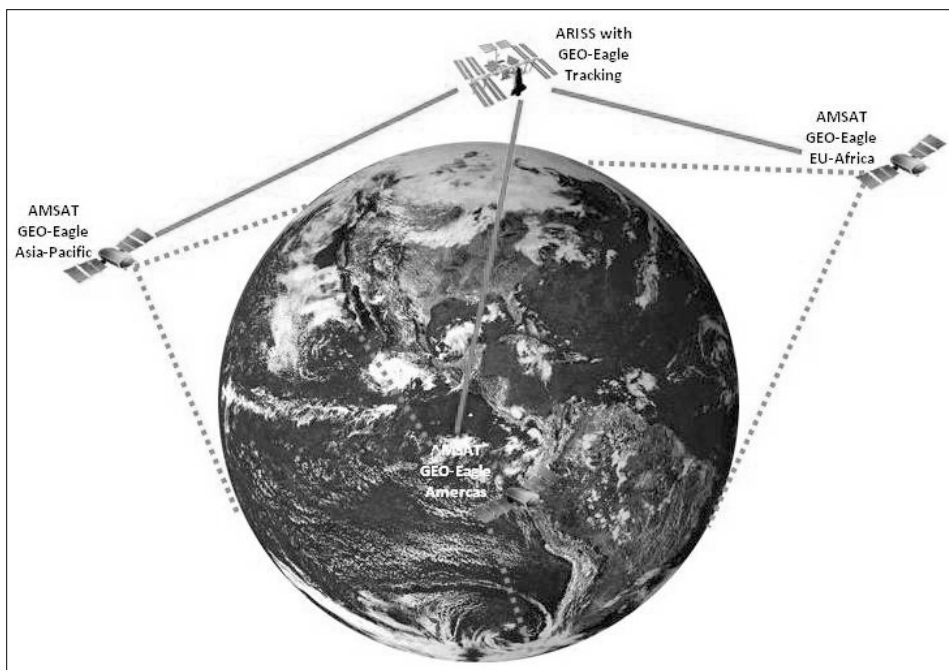


Figure 4: Imagine the possibilities! Of course we need to build and deploy AMSAT GEO-Eagle-Americas, AMSAT-GEO-Eagle-EU-Africa, AMSAT GEO-Eagle-Asia-Pacific, along with GEO-Eagle tracking capability for ARISS on-board ISS to access our birds.

Sample Elevation Angles to GEO-Eagle at 130° W	
Cities	Estimated Antenna Elevation
Boston	14.7°
Chicago	26.3°
Quebec	13.0°
Anchorage	18.5°
Newfoundland	0.5°
Auckland, NZ	18.1°

Table 1: Antenna Elevation Angles to GEO-Eagle.

the classroom or school laboratory. These experiments can be located inside the environment of the ISS or can be on the outside of the station. Continuous earth and space observation will become available in the classroom.

An Example of Amateur Radio Communications Coverage from Geostationary Orbit

If a geostationary ride-share opportunity becomes available, AMSAT will need to accept any orbital parameters being offered. The good news is that perhaps opportunities for several geostationary ride-share orbital slots will arise over the years as the primary satellites require periodic replacement. These future opportunities will allow us to build our GEO-Eagle constellation.

Tom Clark, K3IO, discusses his “strawman” proposal for GEO-Eagle in his paper,

“Taking Eagle to New Heights” and accompanying presentation at the 2008 AMSAT Space Symposium. Tom presented examples of coverage based on a hypothetical situation which offers us a ride-share to a geostationary slot over the equator at 130° W. Table 1 shows estimated antenna elevations for selected cities around the perimeter of the subsatellite footprint.

Introducing Amateur Radio’s Classroom in the Sky

As you can see in Figure 5, the GEO-Eagle provides multiple user access to many

Amateur Radio ground stations. One of the access methods under study for the Advanced Communication Package involves multiple stations uplinking via the 5650-5670 MHz band. A broadband downlink on 3400-3410 MHz transmits a multiplexed signal which is decoded by your ACP ground station. This is analogous to the downlink method employed by DirecTV or Dish network where all the television channels are delivered simultaneously and your set top box selects your desired channel. The communications payload also plans to include bandwidth to support the conventional, linear bent-pipe transponders.

The ACP digital channels are being planned to handle GEO-Eagle communication from user classifications determined by how well you can access the satellite based on your location, antenna configuration and station equipment. Basic access includes voice transmission and reception while advanced access includes video.

GEO-Eagle can deliver on-going learning and training right to your shack. These can be live presentations with the instructor uplinking at scheduled times, or with a little computer server work stored presentations could be delivered on-demand. Imagine having training such as this delivered to your shack ...

- Classes for new hams (you’ll have to invite them over to your shack)
- License upgrade classes
- FEMA basic preparedness training classes
- Specialized topics such as digital signal processing, antenna design, station

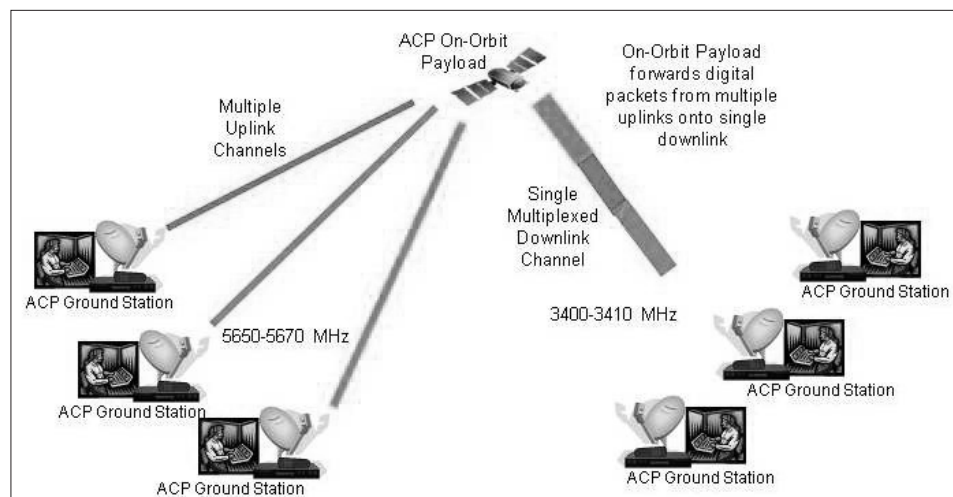


Figure 5: Advanced Communications Package multi-user network design proposed by Tom Clark, K3IO. Tim Salo, AB0DO, proposed an IP-based design for the earth stations and satellite, greatly expanding the transport of multiple user applications such as voice, video and data. Both papers were presented at the 2008 AMSAT Space Symposium in Atlanta, Georgia.





... continued from previous page.

improvement

- ARRL's on-line classes

Various Amateur Radio news services delivering the latest information could be available ...

- AMSAT Nets
- ARRL Bulletins
- Amateur Radio Newline
- This Week in Amateur Radio

And finally, the ACP will provide opportunities to provide coverage for special events never before available in high quality in your shack, including ...

- AMSAT Meetings
- Symposium and Colloquium coverage
- Launch coverage

Actually the list is endless, limited only by our imagination. First of all, we will need to build and launch the GEO-Eagle constellation. This is where you come in. Please consider joining the AMSAT team and see where you can help – see our “Help Wanted” notice in this issue!

Footnotes

- [1] Part Two will examine the role of AMSAT-Eagle in supporting disaster communications; Part Three will examine the role of AMSAT-Eagle in supporting humanitarian missions around the globe, and Part Four will examine the role of AMSAT-Eagle in supporting the Military Affiliate Radio System.
- [2] K3IO AMSAT Symposium Paper
- [3] TDRSS – Tracking Data Relay Satellite System which provides NASA's geostationary network relay for ISS systems and experiments.

References

Taking Eagle to New Heights – A Strawman Design for a Geostationary Amateur Radio Satellite, Tom Clark, K3IO. Proceedings of the AMSAT-NA 2008 AMSAT Space Symposium, Atlanta, Georgia. October 24-26, 2008.

Proposed Network-Centric Architecture for the Advanced Communications Package (ACP), Timothy Salo, AD0DO. Proceedings of the AMSAT-NA 2008 AMSAT Space Symposium, Atlanta, Georgia. October 24-26, 2008. 

and W3JCT, “AMSAT's New Spacecraft Integration Lab after 14 Months”, March/April 2008, pp. 23-25). This article provides an excellent overview of the key features of the lab facility.

For reasons not clear to AMSAT, HISS dramatically altered its mission, corporate structure and focus over the summer. A ‘major investor’ apparently purchased 49% of HISS and changed the organization to a ‘for profit’ corporation. The new company was redefined as a ‘full service engineering company.’

Suddenly, AMSAT was apparently no longer seen as a positive relationship by the new HISS management. The deteriorating situation came to a head when HISS removed some AMSAT equipment without our permission and placed it in a storage pod located outside the facility. They also took down the AMSAT banners to hide AMSAT's presence. AMSAT volunteers were restricted from entering the Lab and were not allowed by HISS to remove AMSAT equipment. Bob Davis, KF4KSS, resigned from his ‘day job’ at HISS.

In September 2008 AMSAT retained a local Pocomoke City attorney to go to court to seek a remedy that would allow removal of AMSAT's equipment from the HISS facility and to seek compensation to cover the costs of removal of the clean room (including electrical and plumbing to remove the fire suppression system that was just completed), storage of our equipment at a temporary facility and eventual relocation to a location of AMSAT's choice. The legal proceedings continue.

What is now clear is that AMSAT must find a new home for the clean room and our test equipment. Over the past two months we have commenced discussions with several universities. This process is ongoing and no decisions have been made regarding the eventual relocation of our lab. As I indicated during the Annual Meeting in Atlanta, AMSAT is interested in speaking with any not-for-profit organization that has sufficient facilities and might be interested in hosting our Lab. We're looking for a host location where our objectives are not only compatible, but will allow growth and enhancement of our goal to build satellites and expand our educational outreach. Any AMSAT member who may be in a position to help find a new home for the AMSAT Integration Lab is encouraged to contact me.

I am optimistic that AMSAT will recover from this difficult and disappointing situation. Our goal is to be able to have an integration lab that is capable of meeting our future satellite construction requirements located at an institution that will allow AMSAT to develop the next generation of satellites and to expand our educational outreach.

This year (2009) will be one of both promise and challenge. AMSAT has a number of exciting opportunities on the horizon while also dealing with the challenges of the current economy. I look forward to working with our members and volunteers as we move forward into the new year.

73,

Barry Baines, WD4ASW

AMSAT President 



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High Efficiency VHF Power Amplifier with a Silicon Carbide Transistor for Space Applications

Marc Franco, N2UO, n2uo@arrl.net

Introduction

Achieving high power efficiency from an RF power amplifier is always a desirable feature. This is particularly important in certain applications, like in space or portable hardware, where the available DC power is limited. This paper describes a high efficiency amplifier with a Silicon Carbide (SiC) transistor, operating at 145 MHz. It was specifically designed for AMSAT Eagle's VHF downlink. SiC is a relatively new compound semiconductor technology, which provides high voltage operation, high gain and outstanding operating temperature.

Space Hardware Design Requirements

Designing electronic hardware for a satellite involves many specific requirements. As a result, a space-qualified part is many, many orders of magnitude more expensive than the same part for industrial use. The ultimate goal for space hardware is no failure during the mission. To achieve this high level of reliability, many issues must be taken into account. A spacecraft must be able to operate in a very harsh environment, with high levels of radiation, extreme temperatures, lack of air, and severe vibration and shock during the launch.

Vibration and Shock

Traveling to space in a rocket is not an easy ride. At liftoff and during the following seconds, the rocket engines generate elevated noise levels. This high acoustic pressure results in very intense vibrations in the spacecraft. Also, the different stages of the flight, vehicle separation and rocket firing, are normally produced by pyrotechnics, generating severe shock. Another type of shock is when the rocket breaks the sound barrier.

Most of these vibrations occur in the audio frequency range. Space hardware is tested on vibration tables that simulate the launch. Acoustic testing is performed on space hardware to simulate the conditions the spacecraft will encounter during its journey into space. The testing is normally done with frequencies that range from 10 Hz to 10 KHz.

Space hardware is specially designed to be able to withstand high levels of vibration and shock. It is common practice to use special

glue-like compounds to tack down large components (toroidal cores, connectors, etc.). RF power transistors are also soldered to the heatsink, instead of attaching them with screws.

Operation in vacuum

Due to the lack of air in space, the electronics (also called the "payload") built into the satellite must be able to operate satisfactorily in the vacuum. Since the time the rocket travels through the atmosphere is relatively short, a fast decompression will take place. It is customary to provide tiny holes in the payload enclosures to permit the air to escape.

Another important issue associated with the lack of air is the fact that heat cannot be dissipated by convection like is normally done in equipment designed to operate on the earth's surface. A heatsink in space is only good to transmit the heat from one place to another and eventually radiate some of it to space.

The lack of convection also affects other components like resistors. Their power dissipation capability in vacuum is much lower than at normal atmospheric pressure. Surface mounted resistors and certain integrated circuits also rely on the printed circuit board copper traces to dissipate heat. Since heat is mostly conducted by the printed circuit instead of being dissipated, the via holes that connect the top copper traces to the bottom ground plane are used to conduct the heat to the heatsink, improving in this manner the heat dissipation of the electronic components.

Radiation

The effect of radiation on electronic components is a subject of great concern in space hardware design. This is particularly important for Amateur Radio satellites in an elliptical orbit (also called HEO, or high earth orbit satellites, like Oscar 40), since the satellite will cross the Van Allen radiation belts that circumsolve the earth about twice a day.

Certain electronic components, like metal-oxide-semiconductor (MOS) devices, can suffer from degraded performance due to the effects of radiation to their oxide layer. This results in a drift in the device's parameters.

Other types of failures are called "single

event" and are caused by cosmic rays and high energy protons. They manifest as high current transients, logic circuit momentary failure, etc.

Apart from electronic problems, certain materials, like Teflon, can become brittle if exposed to radiation, which can lead to component failure after a few years.

Temperature

Due to the lack of air, the parts of the satellite that face the sun can get very hot, and the shadow areas extremely cold. It would be an extremely difficult task, or maybe even impossible, to design electronic equipment that could operate under those conditions.

To overcome this problem, most satellites have what are called "heat pipes". These devices consist of hermetically sealed metal tubes that contain a fluid. The continuous evaporation and condensation of the fluid allows the transfer of heat from a warm part to a cooler area of the satellite. As a result, an averaging of the temperature is achieved, avoiding extreme cold or hot areas.

Since the satellite operates in vacuum, all the heat generated by the satellite must eventually be radiated to space.

Thermal stress is another issue that must be considered. Since the satellite components might be subjected to sudden changes in temperature, the expansion and compression of dissimilar materials can lead to cracks and mechanical failure. Typical examples are the tabs of RF power transistors, which must be bent in such a way that they resemble an inverted "u" spring. In this manner, the different expansion coefficients of the transistor materials, the printed circuit board and the metal fixture where the transistor is mounted are compensated for by expanding or compressing the tabs of the transistor.

Multipacting

Multipacting is a phenomenon of resonant electron multiplication in vacuum. It occurs when RF voltage is applied between two metal plates that are in close proximity. This effect is a function of the RF voltage, the frequency and the distance between the metal plates. Multipacting can produce a breakdown effect, leading to the malfunction of an electronic device.

Satellite designers analyze the spacecraft design to identify potential areas where



multipacting can occur. Typically, directional couplers, filters or even small gaps between a printed circuit board and a connector mounted on the wall of an enclosure can present a problem.

The most common cure to multipacting is to fill the gap (vacuum) with a specially designed compound. However, the dielectric properties of the filler might be a problem, so multipacting must be avoided by proper design whenever possible.

Outgassing

Some of the elements that constitute a satellite may slowly release a very small mass of various gases after the spacecraft is placed in orbit. Unfortunately, since the satellite operates in a vacuum, even a tiny amount of gas can cause damage to sensitive parts of the satellite like optics (video cameras and telescopes), heat radiators and solar cells. Outgassing can also be enhanced by radiation effects. Certain plastics, paints, or printed circuit board substrates are typical elements that can cause outgassing problems.

Electronic component derating

The ultimate goal of a satellite payload is to operate correctly during the entire mission. To achieve this high reliability, the electronic components used to manufacture space hardware not only must be carefully selected and controlled, but they must be also operated below their maximum temperature, voltage, current and power ratings. This technique is called derating. Component derating is usually indicated as a percentage of the nominal component specification.

Tin, cadmium and zinc whiskers

When pure tin, cadmium and zinc are used in space, it is possible that a conductive, single crystal structure called "whisker" can grow producing catastrophic short circuits that can jeopardize a mission. These whiskers are just a few microns in diameter, but can grow up to half an inch in length.

Sometimes, the circuit has enough current capability to fuse the whisker (between 10 and 50 mA), so the failure could be momentary.

Component traceability during manufacture

Regular components for industrial or commercial applications are manufactured under various processes. Sometimes, a manufacturer will introduce changes to some of those processes, without affecting the performance of the component. However, this

may lead to trouble in space applications due to the radiation levels, sudden temperature changes and high vacuum.

High Efficiency VHF Class-E Amplifier

The following text is based on "Class-E Silicon Carbide VHF Power Amplifier", by Marc Franco and Allen Katz, presented at the IEEE International Microwave Symposium 2007 in Honolulu, Hawaii [1]. The original publication is copyright of the IEEE, who granted permission to use portions of the original work in this paper. Cree, the manufacturer of the SiC device used in the amplifier, made the IEEE paper available on their corporate Web site [2].

Class-E amplification

Not all the DC power delivered by the power supply will be converted into RF power by the amplifier. Unfortunately, part of the DC power will be turned into heat. For space applications, where every watt of DC power is very expensive and heat dissipation is of great concern due to the lack of air, it is very important to maximize the RF power amplifier efficiency.

Most of the energy lost as heat is due to the fact that linear amplifiers operate the active devices in such a way that there is a voltage drop and significant current flowing through them simultaneously. The product of that voltage and current is the energy that turns into heat. If we could avoid that situation, that is, having no current when the voltage is maximal, and vice versa, then the power dissipated by the active device would be minimized.

One way to achieve the above conditions

is to operate the active device as a switch. In this way, when the switch is closed, the voltage is zero and the current is maximal, and when the switch is open, the voltage is maximal and the current is zero.

Class-E amplification was developed by Nathan Sokal, WA1HQC, and Alan Sokal WA1HQB [3] [4]. As shown in Figure 1, a Class-E amplifier operates the active device as a switch. However, since a transistor has certain amount of shunt capacitance at the output, it does not look like an ideal switch. A Class-E amplifier has an ad-hoc wave-shaping LC network at its output that absorbs the transistor output capacitance, and as a result, achieves almost perfect switch performance and very high efficiency.

Unfortunately, Class-E amplifiers are nonlinear, that is, their output signal is not exactly a larger replica of the input signal. This means that SSB or any other envelope-varying signal cannot be amplified with low distortion.

Class-E amplifiers can achieve efficiencies in the high nineties. The limiting factors are usually the series resistance of the active device, and losses in the output matching and wave-shaping networks.

Class-E Silicon Carbide 145 MHz amplifier design

The amplifier's design goal was an output power of 20 watts at a frequency of 145 MHz, with no tunable parts, 100 KHz bandwidth and harmonics and spurs at least 60 dB below the carrier. Cree's CRF24060 SiC MESFET was chosen as the active device for its high breakdown voltage, lack of internal matching and availability of a

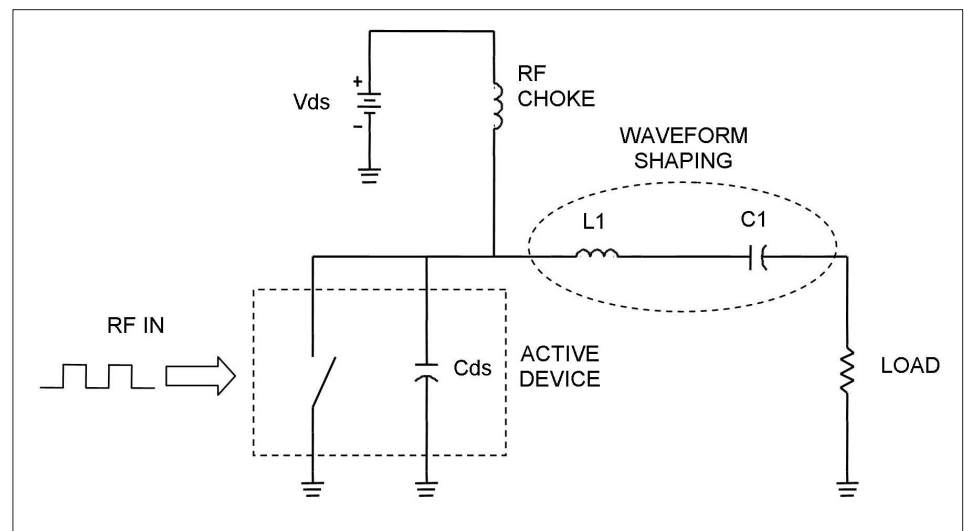


Figure 1: Class-E RF power amplifier concept.

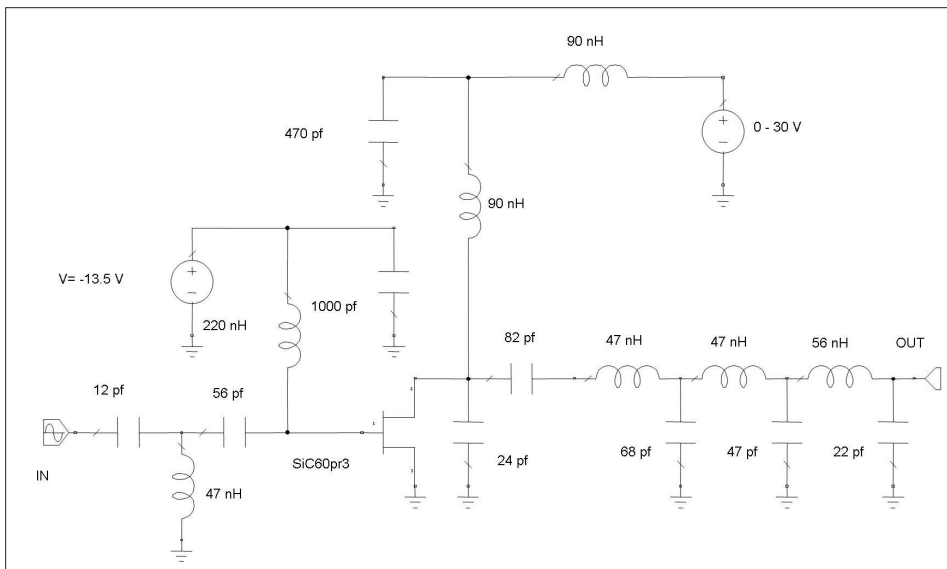


Figure 2: Schematic diagram of the SiC VHF power amplifier.

nonlinear model. The amplifier's schematic diagram is shown in Figure 2.

The output waveform shaping network was designed according to the equations provided in [4] for a Q of 2.27. A maximum drain voltage of 30 V was used to avoid exceeding the device's maximum drain voltage.

The output load impedance of approximately 18 ohms was matched to 50 ohms with an L network that shares the inductor with the waveform shaping network. Finally, a low pass filter section for improved spectral purity was utilized.

The input of the active device was matched to 50 ohms by means of a high pass filter network to prevent the attenuation of the high frequency components of the drive signal.

Since it was desired to provide linear amplification by restoring the input signal's envelope with drain amplitude modulation [5] [6] [7], the drain bias network was built

with a low pass filter that allows drain amplitude modulation frequencies of up to a few MHz to pass through it with minimum attenuation, while at the same time providing acceptable isolation at the carrier frequency and its harmonics.

The amplifier component values were optimized with AWR's Microwave Office nonlinear simulator. Every effort was made to utilize standard value components and to avoid the use of trimmer capacitors or adjustable inductors.

The amplifier prototype, shown in Figure 3, was implemented on a Rogers 6002 30 mil substrate for its excellent outgassing and thermal characteristics, which makes it suitable for space applications. ATC 700B standard value ceramic capacitors were used for the matching and biasing networks. Coilcraft air spring inductors with 2% tolerance were utilized throughout the design; however, the flight unit will employ inductors with no plastic coating.

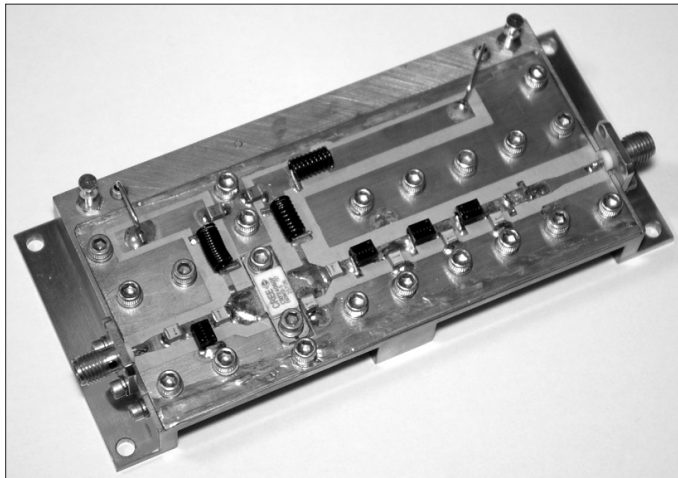


Figure 3: High efficiency SiC MESFET Class-E VHF amplifier.

Performance as a function of drain voltage

Figure 4 shows the amplifier RF output power as a function of drain voltage. This test was carried out with a constant input power level of 27 dBm, achieving the desired output power of 20 watts and a power gain of 16 dB. Only the fundamental component of the output was considered in this

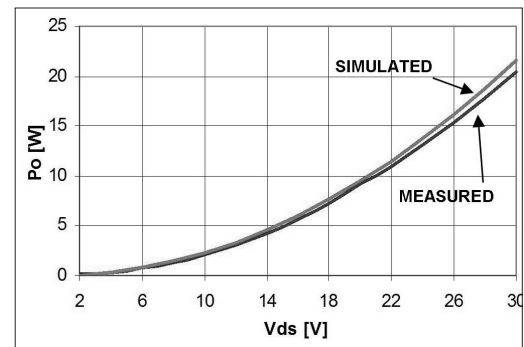


Figure 4: RF output power as a function of drain voltage.

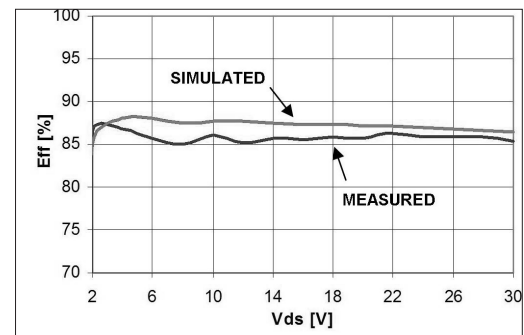


Figure 5: Drain efficiency as a function of drain voltage.

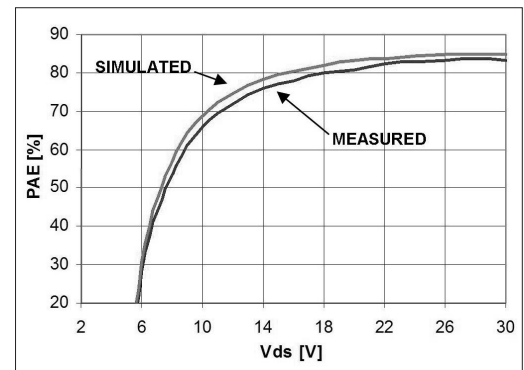


Figure 6: Power added efficiency as a function of drain voltage.

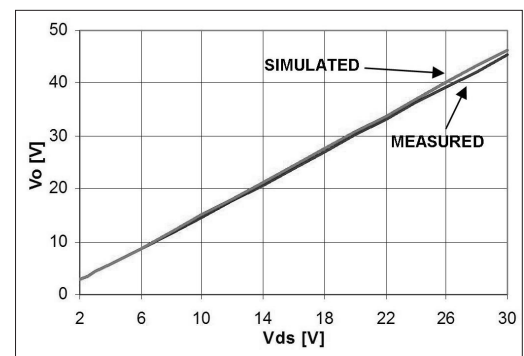


Figure 7: RF peak output voltage as a function of drain voltage.

measurement since the amplifier has a built-in low pass filter and all harmonics and spurs were at least 60 dB below the fundamental.

The drain efficiency as a function of drain voltage is shown in Figure 5. This efficiency

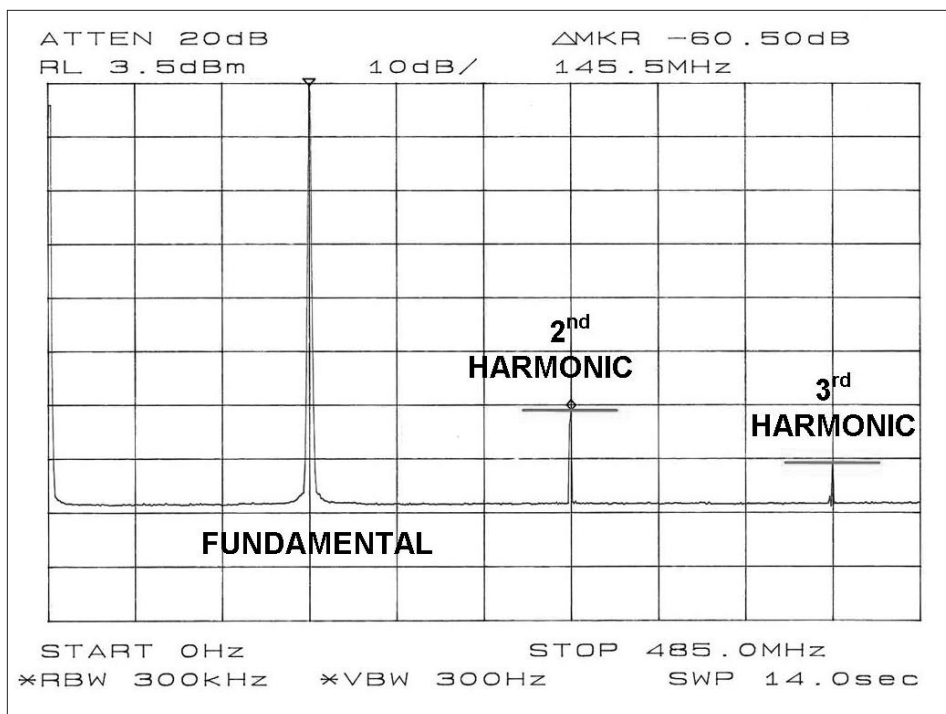


Figure 8: Measured output spectrum.

was again measured at a constant input power level of 27 dBm. The efficiency was approximately constant and around 86% from a drain voltage of 2 V up to the maximum drain voltage of 30 V.

Figure 6 shows the power added efficiency (PAE) of the amplifier for a constant drive level of 27 dBm.

The RF peak output voltage as a function of drain voltage is shown in Figure 7 and illustrates the amplifier's excellent drain voltage to RF voltage linearity.

Spectral purity

Figure 8 shows the measured output spectrum of the amplifier. The simulation predictions and measured level for the second harmonic were identical at 58 dB

below the fundamental. However, the measured third harmonic was approximately 20 dB higher due to coupling effects not taken into account during the simulation.

Conclusion

A high-efficiency Class-E amplifier was designed, simulated and demonstrated practically. The simulation and the experimental results agreed so closely that no component value changes were necessary.

A silicon carbide MESFET was used as the active device. This semiconductor technology has not been previously reported to be successful in producing very high efficiency VHF amplifiers. Since SiC devices operate from higher voltages than GaAs

devices, they can be advantageously used in Class-E designs. Given the possibility of SiC devices becoming space qualified, they could constitute the semiconductor of choice for these applications.

The most significant simulation and experimental results are summarized in Table I. A maximum drain DC to RF efficiency of 86.8 % was achieved. All measurements were done at a constant input power level of 27 dBm. The maximum power added efficiency for this drive level was measured at 83.5 %. A 20.5 watt output power level was reached at a 30 V drain voltage.

References

- [1] M. Franco, A. Katz, "Class-E Silicon Carbide VHF Power Amplifier", *IEEE-MTT-S International Microwave Symposium Digest*, Honolulu, Hawaii, June 2007.
- [2] http://www.cree.com/products/wireless_docs.htm
- [3] N. Sokal and A. Sokal, "Class E – A New Class of High-Efficiency Tuned Single-Ended Switching Power Amplifiers," *IEEE Journal of Solid-State Circuits*, June 1975
- [4] N. Sokal WA1HQC, "Class-E RF Power Amplifiers", *QEX*, January 2001.
- [5] L. R. Kahn, "Single Sideband transmission by Envelope Elimination and Restoration," *Proc. IRE*, vol. 40, no. 7, pp. 803-806, July 1952.
- [6] http://www.amsat-dl.org/dl/HELAPS_en.pdf
- [7] <http://www.amsat-dl.org/dl/HelapsTechnologyTransferSeminar.pdf>

Parameter	Simulated	Measured
Maximum Output Power	21.5 W	20.5 W
Nominal Input Power	27 dBm	27 dBm
Maximum Drain Efficiency	88 %	86.8 %
Maximum Power Added Efficiency	84.8 %	83.5 %
Maximum spurs and harmonics	-58 dBc	-58 dBc

Table 1: SiC VHF Power Amplifier – Simulated and experimental results.



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